CODE MET292	COURSE NAME CONTINUUM MECHANICS	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble:

At the end of the course the students will have a comprehensive, systematic and integrated knowledge of the principles of continuum mechanics. They be conversant with physical laws and analytical tools such as tensor calculus required to formulate and solve continuum problems. Also they have an in-depth understanding of the common principles which underlie the disciplines of solid mechanics and fluid mechanics – hitherto considered mostly separate. The course equip the students to pursue further specialized areas of study such as aeroelasticity, nonlinear mechanics, biomechanics etc. which are essentially based on continuum mechanics.

Prerequisite:

MECHANICS OF SOLIDS

Course Outcomes:

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

CO 1	**Make use of the concepts of tensor formalism for practical applications**
CO 2	**Apply deformation and strain concepts for practical situations**
CO 3	**Identify stresses acting on components subjected to complex loads**
CO 4	**Make use of fundamental laws for problem formulations and mathematical modeling**
CO 5	**Develop constitutive relations and solve 2 D elasticity problems**

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO 11	PO 12
CO 1	3				2				2			3
CO 2	3	3	3		2	1			2			3
CO 3	3	3	3		2	1			2			3
CO 4	3								2			3
CO 5	3	3	3		2	1			2			3

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern:

There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

COURSE LEVEL ASSESSMENT QUESTIONS

Course Outcome 1

1. With the help of mathematical derivations obtain the relation between circulation of a vector field per unit area around a point in a plane and curl of the vector.
2. Prove the vector identity $u \times (v \times w) = (u.w)v - (u.v)w$
3. Show that a) $\delta_{3p} v_p = v_3$ b) $\delta_{3i} A_{ji} = A_{j3}$

Course Outcome 2

1. Discuss the physical interpretations of components of Linearized strain tensor.
2. Given the displacement components $u_1 = k{x_2}^2, u_2 = 0,\ u_3 = 0,\ k = 10^{-4}$, obtain infinitesimal strain tensor E
3. Given $x_1 = X_1 + 2X_2,\ x_2 = X_2, x_3 = X_3,$ obtain the right Cauchy Green deformation tensor, right stretch tensor and rotation tensor.

Course Outcome 3

1. Given a continuum, where the stress state is known at one point and is represented by the Cauchy stress tensor components $[\sigma_{ij}] = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 2 \end{bmatrix}$Pa, find the principal stresses and principal directions.
2. The stress state at one point is represented by the Cauchy stress components $[\sigma_{ij}] = \begin{bmatrix} \sigma & a\sigma & \boldsymbol{b}\sigma \\ a\sigma & \sigma & c\sigma \\ b\sigma & c\sigma & \sigma \end{bmatrix}$, where a, b, c constants are and σ is the value of the stress. Determine the constants such that the traction vector on the octahedral plane is zero.
3. Find the maximum principal stress, maximum shear stress and their orientations for the state of stress given $[\sigma_{ij}] = \begin{bmatrix} 6 & 9 & 0 \\ 9 & -6 & 0 \\ 0 & 0 & 3 \end{bmatrix}\ MPa$

Course Outcome 4

1. Explain Reynold's Transport Theorem
2. Prove the symmetry of stress using principle of conservation of angular momentum.
3. Obtain the Eulerian form of continuity equation

Course Outcome 5

1. From linear elastic constitutive relation for isotropic materials, deduce the strain stress relation $\varepsilon_{ij} = \frac{1+\nu}{E}\ \sigma_{ij} - \frac{\nu}{E}\sigma_{kk}\delta_{ij}$
2. Formulate the stress compatibility equation for plain strain problems in the absence of body force.
3. Derive the stress compatibility equation for a plain stress problem with body force. State the condition under which it becomes the biharmonic equation.

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

IV SEMESTER B.TECH DEGREE EXAMINATION

Course Code : MET292

Course Name : CONTINUUM MECHANICS

PART A

Each question carries three marks

1. Differentiate between vector space and inner product space.
2. Prove div (**A** x **B**) = curl **A**.**B** – curl **B**.**A**, using indicial notation.
3. Differentiate between Lagrangian and Eulerian description of fluid motion.
4. The Lagrangian coordinate of a material particle is $(x(t), y(t), z(t))$. Obtain the mathematical expression for the component of acceleration along the direction of motion of the material particle.
5. Derive an equation for octahedral shear stress in terms of the stress invariants.
6. The Cauchy stress tensor at a point P is given $\sigma ij = \begin{bmatrix} 5 & 6 & 7 \\ 6 & 8 & 9 \\ 7 & 9 & 2 \end{bmatrix}$ GPa. Obtain the deviatoric and volumetric parts of the tensor.
7. Deduce the equilibrium equations from linear momentum principle.
8. Express the local and global form of Reynold's Transport Theorem.
9. Write down the stress strain relations of a linear elastic isotropic material.
10. Write down the radial and tangential components of stress in terms of Airy's stress function.

PART B

Answer one full question from each module.

MODULE 1

11 a) Evaluate using indicial notation (8)

i. $\mathbf{u} \times (\mathbf{v} \times \mathbf{w})$
ii. $(\mathbf{uv}) : (\mathbf{ws})$

b) Expand using summation convention (6)

iii. $\rho \dot{v}_i = \rho b_i + \sigma_{ij,j}$
iv. $e'_i = Q_{mi} e_m$

OR

12 a) Prove that $[A \quad B \quad C][D \quad E \quad F] = \begin{bmatrix} A.D & A.E & A.F \\ B.D & B.E & B.F \\ C.D & C.E & C.F \end{bmatrix}$, from there show that

$$e_{ijk}e_{rst} = \begin{bmatrix} \delta_{ir} & \delta_{is} & \delta_{it} \\ \delta_{jr} & \delta_{js} & \delta_{jt} \\ \delta_{kr} & \delta_{ks} & \delta_{kt} \end{bmatrix}$$ (9)

b) Establish the identity $e_{ijk}e_{mnk} = \delta_{im}\delta_{jn} - \delta_{in}\delta_{jm}$ (5)

MODULE 2

13 a) Given the motion of a body $x_i = X_i + 0.2tX_2\delta_{1i}$, for a temperature field given by $\theta = 2x_1 + (x^2)^2$, find the material description of temperature and the rate of change of temperature of a particle at time t=0 , which was at the place (0,1,0). (8)

b) Derive compatibility equation (6)

OR

14 a) Given that $[F] = \begin{bmatrix} \sqrt{3} & 1 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$, determine the left and right stretch tensors. (14)

b) Explain infinitesimal deformation theory.

c) Obtain an expression for Linearized strain.

MODULE 3

15 a) The stress matrix in MPa when refereed to axes $Px_1x_2x_3$ is (14)

$$[\sigma_{ij}] = \begin{bmatrix} 3 & 10 & 0 \\ -10 & 0 & 30 \\ 0 & 30 & -27 \end{bmatrix}$$

Determine

i. the principal stresses
ii. principal planes
iii. maximum shear stress
iv. Octahedral normal and shear stress

OR

16 a) The principal stresses of stress at a point are σ_1, σ_2 and σ_3 with $\sigma_1 > \sigma_2 > \sigma_3$. Now derive equations of the direction cosines of a plane passing through this point, which is subjected to normal and shear stress σ_n and τ_n respectively. (6)

b) For the stress state given

$$[\sigma_{ij}] = \begin{bmatrix} 12 & 9 & 0 \\ 9 & -12 & 0 \\ 0 & 0 & 6 \end{bmatrix} MPa$$

where the Cartesian coordinate variables X_i are in meters and the unit of stress are MPa. Determine the principal stresses and principal directions of stress at the point $X = e_1 + 2e_2 + 3e_3$. (8)

MODULE 4

17 a) Derive the differential form of conservation of energy. (4)

b) What is localization theorem? Write down its relevance in the derivation of differential equations. (6)

c) Derive the Cauchy's equation of motion using the conservation of linear momentum principle (4)

OR

18 a) Prove the symmetry of stress $\sigma_{ij} = \sigma_{ji}$ using principle of conservation of angular momentum. (8)

b) Obtain the Eulerian form of continuity equation. (6)

MODULE 5

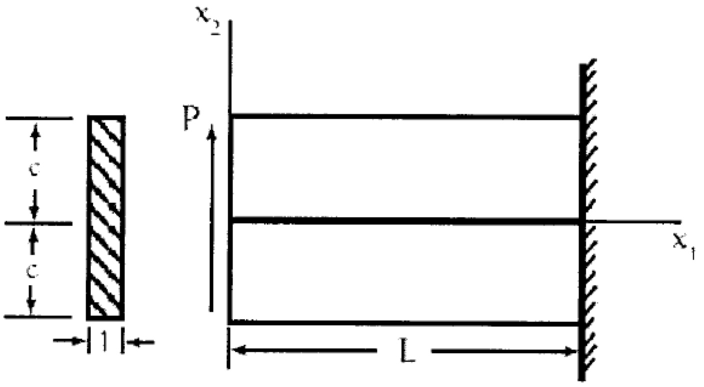
19 a)Show that for an isotropic elastic medium (6)

a. $\lambda = \frac{E\nu}{(1+\nu)(1-2\nu)}$ b) $\mu = \frac{E}{2(1+\nu)}$

b. Determine the radial stress and tangential stress developed in a thick cylinder of internal radius '*a*' and external radius '*b*' subjected internal pressure P_i and external pressure P_o using stress function method. (8)

OR

20 Consider a special stress function having the form $\phi = B_2 x_1 x_2 + D_4 x_1 x_3$. Show that this stress function ma)'- be adapted to solve for the stresses in an end-loaded cantilever beam as shown in the sketch. Assume the body forces are zero for this problem. (14)



SYLLABUS

Module 1

Mathematical preliminaries - Index notation, Einstein's summation convention- Kronecker delta and Levi-Civita symbols, Cartesian basis- Concept of tensor- Tensor as a linear transformation - Vector as a first order tensor- Coordinate transformation of vectors and tensors.

Principal values, trace and invariants-Gradient, divergence and curl of vector and tensor fields- Vector identities-Gauss' divergence and Stokes' theorems.

Module 2

Concept of continua- Reference and current configuration- Deformation gradient tensor- Lagrangian and Eulerian description of motion.

Polar decomposition theorem- Right and left Cauchy Green tensors- Infinitesimal deformation theory- Linearized strain- Principal strains- Saint Venant's compatibility equations

Module 3

Traction- Cauchy stress tensor- Stress component along orthonormal basis vector- Components of Cauchy stress tensor on any plane.

Principal planes- Principal stress components- Normal and shear stresses- Stress transformation- Equilibrium equations

Module 4

Balance Laws - Reynold's transportation theorem- Localization theorem- Lagrangian and Eulerian forms of equation for mass balance.

Balance of linear momentum equation- Balance of angular momentum- Symmetry of stress tensor- Balance of energy

Module 5

Constitutive relations - Generalized Hooke's law for isotropic materials in indicial and matrix forms- Relation connecting Lame's constants with Young's modulus, Poisson's ratio and Bulk modulus.

2D formulation of field equations; Airy's stress function- Biharmonic equation-Uni axial tension and pure bending of a beam; End loaded cantilever- Polar coordinates- Axisymmetric formulation- Lame's thick cylinder problem- Quarter circle cantilevered beam with radial load.

Text Books

1. G. Thomas Mase, George E. Mase.. Ronald E. Smelser. Continuum mechanics for engineers 3rd ed CRC Press
2. . Lawrence E. Malvern. Introduction to the Mechanics of a Continuous Medium – Prentice Hall

Reference Books

1. J.H. Heinbockel, Introduction to Tensor Calculus and Continuum Mechanics – Open Source
2. W. Michael Lai, David Ribin, Erhard Kaempl, Introduction to Continuum Mechanics 4th Ed., Butterworth- Heinemann
3. J. N. Reddy, An Introduction to Continuum Mechanics with applications - Cambridge University Press
4. Y. C. Fung, A First Course in Continuum Mechanics for Physical and Biological Engineers and scientists - Prentice Hall
5. Han-Chin W, Continuum mechanics and plasticity - CRC Press
6. Sudhakar Nair, Introduction to Continuum Mechanics – Cambridge University press
7. Morton E. Gurtin, An introduction to continuum mechanics, Academic Press
8. S.P. Timoshenko, J.N. Goodier, Theory of Elasticity, 3rd Edition, McGraw Hill Publishing

COURSE CONTENTS AND LECTURE SCHEDULE

Sl. No.	Topic	Number of lecture hours
1	Index notation, Einstein's summation convention- Kronecker delta and Levi-Civita symbols	2
2	Cartesian basis- Concept of tensor- Tensor as a linear transformation - Vector as a first order tensor	1
3	Coordinate transformation of vectors and tensors.	2
4	Principal values, trace and invariants	2
5	Gradient, divergence and curl of vector and tensor fields	2
6	Vector identities-Gauss' divergence and Stokes' theorems.	1
7	Concept of continua- Reference and current configuration, Lagrangian and Eulerian description of motion	2
8	Deformation gradient tensor, Right and left Cauchy Green tensors	2

9	Infinitesimal deformation theory- Linearized strain	2
10	Principal strains	1
11	Polar decomposition theorem	1
12	Saint Venant's compatibility equations	1
13	Traction- Cauchy stress tensor- Stress component along orthonormal basis vector	2
14	Components of Cauchy stress tensor on any plane., Normal and shear stresses	2
15	Principal planes- Principal stress components	2
16	Stress transformation	2
17	Reynold's transportation theorem- Localization theorem, Introduction on Balance Laws	1
18	Lagrangian and Eulerian forms of equation for mass balance.	1
19	Balance of linear momentum, equilibrium equations	1
20	Balance of angular momentum, Symmetry of stress tensor	1
21	Balance of energy	1
22	Constitutive relations - Generalized Hooke's law for isotropic materials in indicial and matrix forms	1
23	Relation connecting Lame's constants with Young's modulus, Poisson's ratio and Bulk modulus.	1
24	2D formulation of field equations; Airy's stress function; Biharmonic equation	4
25	Uni axial tension and pure bending of a beam; End loaded cantilever	1
26	Polar coordinates; Axisymmetric formulation	2
27	Lame's thick cylinder problem	2
28	Quarter circle cantilevered beam with radial load.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET294	ADVANCED MECHANICS OF FLUIDS	VAC	3	1	0	4

Preamble:

This course is a survey of principal concepts and methods of fluid dynamics. Topics include conservation equations, exact solutions of Navier-Stokes Equations, potential flow solutions, Boundary layers; introduction to turbulence and turbulence modelling

Prerequisite:

MET 203- Mechanics of Fluids

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

CO 1	Apply conservation equations of fluid mechanics
CO 2	Use potential flow theory in fluid problems
CO 3	Utilize approximate solutions of the Navier-Stokes equations
CO 4	Compute effect on boundary layers.
CO 5	Explain turbulence and turbulence modelling

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3											
CO 2	3	2	1									
CO 3	3	2	1	1								
CO 4	3	2	1									
CO 5	3	1										

Assessment Pattern

Blooms Category	CA			ESA
	Assignment	Test - 1	Test - 2	
Remember	25	20	20	10
Understand	25	40	40	20
Apply	25	40	40	70
Analyse	25			
Evaluate				
Create				

Continuous Internal Evaluation Pattern:

Attendance : 10 marks

Continuous Assessment Test (2 numbers) : 25 marks

Assignment/Quiz/Course project : 15 marks

Mark distribution & Duration of Examination :

Total Marks	CA	ESE	ESE Duration
150	50	100	3 Hours

End semester pattern:

There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

COURSE LEVEL ASSESSMENT QUESTIONS

Course Outcome 1

1. What is the significance of RTT in the study of transport phenomena.
2. Explain the relationship between the stress tensor and the rate of deformation.
3. Derive the expression for the Navier-Stokes equation and explain the different terms involved.

Course Outcome 2

1. Derive the expression for stream function and potential function of a doublet using the potential flow theory.
2. Derive the expression for lift for flow past a cylinder with circulation.
3. What is the significance of conformal mapping?

Course Outcome 3

1. Derive the expression for the pressure gradient for Couette flow.
2. Explain the working of a Viscometer based on the flow through a rotating annulus.
3. What is Stokes' first problem?

Course Outcome 4

1. Explain the development of boundary layer along a thin flat plate held parallel to a uniform flow. Point out the salient features.
2. Discuss on the effect of pressure gradient on boundary layer separation.
3. Find the thickness of the boundary layer at the trailing edge of a smooth plate of length 5 m and width 1.2 m when the plate is moving at 5 m/s in stationary air. Take the kinematic viscosity of air as 0.11 stokes.

Course Outcome 5

1. What are the semi-empirical theories associated with turbulent flow?
2. Explain the two equation models used in turbulent flow.
3. Distinguish between DNS and LES.

Syllabus

Module 1: Concept of viscosity, stress tensor, relation between stress and rate of deformation, Stokes hypothesis, Reynolds Transport Theorem, Mass, Momentum and Energy conservation, Derivation of Navier-Stokes equations.

Module 2: Potential flow: Uniform flow, source flow, sink flow, free vortex flow and super imposed flow-source and sink pair, doublet, plane source in a uniform flow(flow past a half body), source and sink pair in a uniform flow(flow past a Rankine oval body), doublet in a uniform flow(flow past a circular cylinder). Pressure distribution on the surface of the cylinder. Flow past a cylinder with circulation, Kutta-Juokowsky's law. Complex flow potential, complex flow potentials for source, sink, vortex and doublet. Potential flow between two parallel plates, potential flow in a sector. Introduction to conformal transformation, conformal mapping.

Module 3: Exact Solutions of Navier Stokes Equations. Parallel flow through straight channel and couette flow. Couette flow for negative, zero and positive pressure gradients, flow in a rotating annulus, Viscometer based on rotating annulus. Flow at a wall suddenly set to motion (Stokes first problem)

Module 4: Boundary layer equations; Boundary layer on a flat plate, Prandtl boundary layer equations, Blasius solution for flow over a flat plate, Von- Karman momentum integral equations, Pohlhausen approximation solution of boundary layer for non-zero pressure gradient flow, favorable and adverse pressure gradients, flow separation and vortex shedding. Boundary layer control.

Module 5: Introduction Statistical approach to turbulent flows, Length and time scales and Kolomogrov's energy cascading theory Reynolds averaged Navier Stokes equations, Turbulence modeling. Concept of eddy viscosity and Prandtl's mixing length hypothesis Zero, one and two equation turbulence models and Reynold's stress models. Concepts of LES and DNS.

Text Books

(1) White, F. M. *Viscous Fluid Flow*, McGraw Hill Education; 3 edition, 2017
(2) Schlichting, H. Boundary layer theory. McGraw Hill Education; 7 edition, 2014

COURSE PLAN

Module	Topics	Hours Allotted
I	Concept of viscosity, stress tensor, relation between stress and rate of deformation, Stokes hypothesis, Reynolds Transport Theorem, Mass, Momentum and Energy conservation, Derivation of Navier-Stokes equations.	6-2-0
II	Potential flow: Uniform flow, source flow, sink flow, free vortex flow and super imposed flow-source and sink pair, doublet, plane source in a uniform flow(flow past a half body), source and sink pair in a uniform flow(flow past a Rankine oval body), doublet in a uniform flow(flow past a circular cylinder). Pressure distribution on the surface of the cylinder. Flow past a cylinder with circulation, Kutta-Juokowsky's law. Complex flow potential, complex flow potentials for source, sink, vortex and doublet. Potential flow between two parallel plates, potential flow in a sector. Introduction to conformal transformation, conformal mapping.	7-2-0
III	Exact Solutions of Navier Stokes Equations. Parallel flow through straight channel and couette flow. Couette flow for negative, zero and positive pressure gradients, flow in a rotating annulus, Viscometer based on rotating annulus. Flow at a wall suddenly set to motion (Stokes first problem)	6-2-0
IV	Boundary layer equations; Boundary layer on a flat plate, Prandtl boundary layer equations, Blasius solution for flow over a flat plate, Von- Karman momentum integral equations, Pohlhausen approximation solution of boundary layer for non-zero pressure gradient flow, favorable and adverse pressure gradients, flow separation and vortex shedding. Boundary layer control.	8-3-0
V	Introduction Statistical approach to turbulent flows, Length and time scales and Kolomogrov's energy cascading theory Reynolds averaged Navier Stokes equations, Turbulence modeling. Concept of eddy viscosity and Prandtl's mixing length hypothesis Zero, one and two equation turbulence models and Reynold's stress models. Concepts of LES and DNS.	7-2-0

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

IV SEMESTER B.TECH DEGREE EXAMINATION

MET294 ADVANCED MECHANICS OF FLUIDS

Mechanical Engineering

Maximum: 100 Marks Duration: 3 hours

PART A

Answer all questions, each question carries 3 marks

1. What is Stokes hypothesis?
2. What is the importance of RTT in the study of transport phenomena?
3. What are the different elementary flows used in potential flow theory?
4. Draw the stream-lines and potential lines for a doublet in a uniform flow and mark the different regions.
5. With a neat sketch explain the Stokes first problem.
6. Draw the velocity profile in Couette flow for negative, zero and positive pressure gradients.
7. With a neat sketch explain the different regions of boundary layer flow over a flat plat
8. What are the different methods employed in controlling the boundary layer separation?
9. Explain Prandtl's Mixing length theory.
10. What is the importance of Turbulence Modeling in fluid dynamics?

(10×3=30 Marks)

PART B

Answer one full question from each module

MODULE-I

11. (a) Derive Reynolds Transport Theorem. (7 Marks)

    (b) Derive the expression for the law of conservation of mass from RTT. (7 Marks)

12. (a) Derive Navier-Stokes equations in Cartesian coordinate system. (10 Marks)

    (b) Write the expanded form of Navier-Stokes equations in Cartesian coordinate system. (4 Marks)

MODULE-II

13. (a) Explain uniform flow with source and sink. Obtain an expression for stream and velocity potential function and show their approximate distribution. (7 Marks)

    (b) A uniform flow with a velocity of 2m/s is flowing over a source placed at the origin. The stagnation point occurs at $(-0.398, 0)$. Determine: (i) Strength of the source, (ii) Maximum width of Rankine half-body and (iii) Other principal dimensions of the Rankine half-body. (7 Marks)

14. (a) A uniform flow with a velocity of 3m/s is flowing over a plane source of strength 30m^2/s. The uniform flow and source flow are in the same plane. A point P is situated in the flow field. The distance of the point P from the source is 0.5m and it is at an angle of 30° to the uniform flow. Determine: (i) stream function at point P (ii) resultant velocity of flow at P and (iii) location of stagnation point from the source.hfill (10 Marks)

    (b) Describe the following terms: i)Complex flow potential ii) Conformal mapping(4 Marks)

MODULE-III

15. (a) An oil of viscosity 18 poise flows between two horizontal fixed parallel plates which are kept 150mm apart. The maximum velocity of flow is 1.5m/s. Find:

       i. The pressure gradient
       ii. The shear stress at the two horizontal parallel plates
       iii. The discharge per unit width for laminar flow of oil.

       (7 Marks)

    (b) Explain the significance of Navier-Stokes equation in viscous fluid flow. Derive the expression for flow in a rotating annulus from the Navier-Stokes Equation. (7 Marks)

16. (a) Derive the expression for pressure gradient in the parallel flow through a straight channel. (7 Marks)

    (b) Explain the working of a Viscometer based on the flow through a rotating annulus. (7 Marks)

MODULE-IV

17. (a) Explain the essential features of Blasius method of solving laminar boundary layer equations for a flat plate. Derive an expression for boundary layer thickness from this solution. (7 Marks)

(b) For the velocity profile for laminar boundary layer flows given as

$$\frac{u}{U} = 2(y/\delta) - (y/\delta)^2$$

find an expression for boundary layer thickness (δ), shear stress (τ_0) and co-efficient of drag (C_D) in terms of Reynold number. (7 Marks)

18. (a) For the velocity profile in laminar boundary layer as,

$$\frac{u}{U} = \frac{3}{2}\left(\frac{y}{\delta}\right) - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$$

find the thickness of the boundary layer and the shear stress 1.5 m from the leading edge of a plate. The plate is 2m long and 1.4m wide and is placed in water which is moving with a velocity of 200mm per second. Find the total drag force on the plate if μ for water = .01 poise. (7 Marks)

(b) Derive Von Karman momentum integral equation for boundary layer flows.(7 Marks)

MODULE-V

19. (a) Explain and differentiate DNS and LES. (7 Marks)

(b) What is the difference between zero equation, one equation and two equation models in turbulent flow? (7 Marks)

20. (a) Explain in detail any one of the two equation models. (7 Marks)

(b) Explain Kolmogrovs energy cascade theory. (7 Marks)

MET 296	MATERIALS IN MANUFACTURING (HONORS)	CATEGORY	L	T	P	Credits	Year of Introduction
		VAC	3	1	0	4	2019

Preamble: Understanding of the correlation between the chemical bonds and crystal structure of metallic materials to their mechanical properties.

Recognize the importance of deformation of metals at high temperature.

Enrich knowledge of various behavior and property changes inside the material structure in raised temperature and methods to strengthening the material.

Provide in-depth proficiency in material science and engineering fields for elevated temperature applications.

Prerequisite: MET 202 - Metallurgy and Material Science

Course Outcomes - At the end of the course students will be able to

CO 1	Understand the chemical bonds, crystal structures and their relationship with the properties.
CO 2	Correlate structure and properties relationship for high temperature applications.
CO 3	Understand the attributes and purity obtainable through triple vacuum induction melting process.
CO 4	To have knowledge in improving material strength against high temperature environment and predict life time.
CO 5	Understand the properties of super alloys and its strengthening processes.

Mapping of course outcomes with program outcomes (Minimum requirements)

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**
CO 1	-	3	-	-	-	-	-	-	-		-	-
CO 2	-	-	3	-	-	-	-	-	-	-	-	-
CO 3	-	-	-	3	-	-	-	-	-	-	-	-
CO 4	3	-	-	-	-	-	-	-	-	-	-	-
CO 5	-	-	-	-	-	-	-	-	-	-	-	3

ASSESSMENT PATTERN

Bloom's taxonomy	Continuous Assessment Tests		End Semester Examination (Marks)
	Test 1 (Marks)	Test 11 (Marks)	
Remember	25	25	25
Understand	15	15	15
Apply	30	25	30
Analyze	10	10	10
Evaluate	10	15	10
Create	10	10	10

Mark distribution

Total Marks	CIE marks	ESE marks	ESE duration
150	50	100	3 Hours

Continuous Internal Evaluation (CIE) Pattern:

Attendance	10 marks
Regular class work/tutorials/assignments	15 marks
Continuous Assessment Test (2 numbers)	25 marks

End semester pattern:- There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Part -A

Course Outcome 1 (CO1): Understand the chemical bonds, crystal structures and their relationship with the properties.

1. Why electrons of higher principal quantum number form weaker bonds.
2. Postulate why ionic and covalent bonded material exhibit bad conductors of heat and electricity?
3. What are the roles of surface imperfections on crack initiation.
4. Which mechanism of strengthening is the Hall- Petch equation related to?

Course Outcome 2 (CO2): Correlate structure and properties relationship for high temperature applications.

1. Nickel has an atomic weight of 58.71, a number which arises from the relative proportions of isotopes of weights 58, 60, 61, 62 and 64. Why is there little contribution from the isotopes of weight 59 and 63?
2. Comparison of the rates of interdiffusion of the transition group metals (the solutes) with nickel (the solvent) indicates that (i) the interdiffusion rate increases with increasing misfit strain between solvent and solute and (ii) the activation energy for interdiffusion decreases with increasing misfit strain. Why might these observations be contrary to expectation? How might this apparent anomaly be rationalised?

Course Outcome 3 (CO3): Understand the attributes and purity level obtainable through triple vacuum induction melting process.

1. What is the need of vacuum for obtaining purifying metals?
2. What are conditions for freckle formation and how can be eliminated?
3. Explain the need of electrode quality in ESR and VAR process?
4. Which are the factors governs the quality of vacuum arc remelting process.

Course Outcome 4 (CO4): To have knowledge in improving material strength against high temperature environment and predict life time.

1. Explain why it might not be sensible, even for single-crystal superalloys, to eliminate completely the grain-boundary strengtheners such as carbon and boron from the melt chemistry.
2. The rate of oxide formation in Al_2O_3 forming single-crystal superalloys is greatly increased with additions of Ti to the alloy chemistry. Explain why this effect occurs.
3. Non-conductive material will you recommend to use at high temperature explain?
4. Both titanium and steel melt at temperatures in excess of 1500 C. Steel can be used at temperatures as high as 1000C but titanium cannot. Why is this?

Course Outcome 5 (CO5): Understand the properties of super alloys and its strengthening processes.

1. The following defects can occur during the casting of single-crystal components:(i) high-angle grain boundaries, (ii) freckles and (iii) spurious grains. What is meant by these terms? Give a brief explanation of the origin of each effect.
2. Suggest a high electrical conductive material which can use at 1100C.
3. Give two reasons why the use of titanium alloys is increasing at the expense of aluminum in both civil and military aircraft.

SYLLABUS

MODULE - 1

Atomic structure- chemical bonds-crystallography-miller indices - slip - dislocation - crystallization- frank-reed source - Structural parameters in high-temperature deformed metals - dislocation structure - distances between dislocations in sub-boundaries - sub-boundaries as dislocation sources and obstacles -dislocations inside sub-grains - vacancy loops and helicoids - structural peculiarities of high - temperature deformation.

MODULE - II

Characteristics of high-temperature materials - The super alloys as high-temperature materials- The requirement: the gas turbine engine- Larson–Miller approach for the ranking of creep performance-development of the super alloys- Nickel as a high-temperature material: justification- super alloy production methods:- vacuum induction melting (VIM), vacuum arc remelting (VAR), VIM, electroslag remelting (ESR),VIM, ESR, VAR- Freckles, three rings, white spot- cleanliness.

MODULE - III

Superalloys:- metallurgy, characteristics - wrought, cast superalloys, properties -crystal structures, phases in superalloys, Iron-Nickel-base superalloys, Nickel-base superalloys, Cobalt-base superalloys, - elements causing brittle phase formation, detrimental tramp elements, elements producing oxidation and hot corrosion resistance- microstructure, gamma prime, gamma double prime, Carbide and Boride phases, strengthening mechanisms- Heat treatment.

MODULE - IV

Single-crystal super alloys for blade applications:- solidification, heat transfer, defects - mechanical behavior, performance in creep, fatigue -Titanium: binary phase diagram - production of ingot - forgings - shear bands - pickling - Ti alloys - machining and welding of Titanium - Heat Treatment - properties of titanium aluminides - Niobium: production of niobium - niobium in steel making – niobium alloys characteristics and applications- Niobium products for the superalloy industry.

MODULE - V

Molybdenum: Ferromolybdenum - production of molybdenum – properties - effect of molybdenum alloying– applications - TZM, TZC- Maraging steel:- reaction in austenite - austenite to martensite transformation- reaction in martensite - time of maraging - precipitate size - fracture toughness - welding and ageing attributes - superior features - applications - cobalt free maraging steel - intermetallics:- phase diagrams- Hume-Rothery phases- structures of $MgCu_2$, $MgZn_2$, $MgNi_2$.

Text Books

1. Callister William. D., Material Science and Engineering, John Wiley, 2014

2. Matthew J. Donachie, Stephen J. Donachie, Super alloys A Technical Guide, Second Edition, 2002 ASM International.

Reference

1. Barrett, C. S. and Massalski, T. B. Structure of metals, Third edition. New York, N.Y., McGraw-Hill Book Company, 1966.
2. Decker, Raymond Frank, Source book on maraging steels: A comprehensive collection of outstanding articles from the periodical and reference literature, Published by American Society for Metals (1979).
3. Gerd Lutjering James C.Williams, Titanium, springer.
4. Roger C. Reed, The Super alloys Fundamentals and Applications, Cambridge university press.
5. Valim Levitin - High temperature strain of metals and alloys - physical fundamentals, Wiley-VCH (2006).
6. https://www.phase-trans.msm.cam.ac.uk/teaching.html

MODEL QUESTION PAPER

MATERIALS IN MANUFACTURING - (HONORS) - MET -296

Max. Marks : 100 **Duration : 3 Hours**

Part – A

Answer all questions.

Answer all questions, each question carries 3 marks

1. NASA's Parker solar probe will be the first-ever mission to "Touch" the Sun. The spacecraft, about the size of a small car, will travel directly into the Sun's atmosphere about 4 million miles from the earth surface. Postulate the coolant used in the parker solar probe with chemical bonds.
2. Explain the structural parameters in time and creep curve for Nickel.
3. Explain the characteristics required for high-temperature materials
4. Explain the ways and means to improve super alloy cleanliness
5. What are the elements causing brittle phase formation in super alloys.
6. Explain the process and need of stress relieving used for super alloys
7. The preferred growth direction of a single-crystal superalloy is (100) Why?
8. Where is hundred percentage pure Titanium is used?
9. What are the special attributes of marging steel welded joint after ageing process?
10. How the structure of intermetallics are determined ?

PART -B

Answer one full question from each module.

MODULE -1

11. a. Explain the basic mechanism involved for metal deformation (7 marks).

b. Explain process involved in high temperature strain of metals and alloys (7 marks).

OR

12. What are the roles played by the fan, compressor, combustor and turbine arrangements in a typical gas turbine engine? How do these affect (i) the pressure and (ii) the average temperature of the gas stream? Explain why your findings justify the use of nickel based superalloys in the combustor and turbine sections, but not in the compressor regions (14 marks).

MODULE -2

13. Explain the justification for the development of super alloys as high temperature alloys (14 marks).

OR

14. Explain the conditions of freckles, three rings and white spots formation and its implications (14 marks).

MODULE -3

15.Explain with neat sketches of different strengthening mechanisms of super alloys with its microstructure (14 marks).

OR

16.Explain different types of heat treatments employed for super alloys (14 marks).

MODULE -4

17. The materials used for high-pressure turbine blade aerofoils are often referred to as single-crystal superalloys. Explain why the use of the term ‘single-crystal’ is disingenuous (14 marks).

OR

18. Explain the process of closed die forging for Titanium alloy manufacturing (14 marks).

MODULE -5

19a. Explain the different reaction in austenite in maraging steel (7 marks).

19b. Explain the Maraging steel hardness produced with aging time versus aging time and different temperatures with neat sketches (7 marks).

OR

20a. Explain the synergetic effect of cobalt and molybdenum in maraging steel with graphs and sketch (7 marks).

20b. Explain structures of $MgCu_2$, $MgZn_2$, $MgNi_2$ with neat sketches (7 marks).

Course content and lecture schedules.

Module	TOPIC	No. of hours	Course outcomes
1.1	Earlier and present development of atomic structure- Primary bonds: Secondary bonds - crystallography-miller indices- slip- crystallization - frank reed source	1	CO1
1.2	Structural parameters in high-temperature deformed metals: structural parameters.	2	CO1
1.3	Dislocation structure - distances between dislocations in sub-boundaries - sub-boundaries as dislocation sources and obstacles.	3	CO1
1.4	Dislocations inside sub-grains - vacancy loops and helicoids - structural peculiarities of high-temperature deformation (levitin).	3	
2.1	Characteristics of high-temperature materials - The superalloys as high-temperature materials.	3	CO1 CO2
2.2	The requirement: the gas turbine engine- Larson–Miller approach for the ranking of creep performance		
2.3	Development of the super alloys- Nickel as a high-temperature material: justification. (Reed).	2	CO2
2.4	Super alloy production methods:- melt routes for super alloys, characteristics, process parameters, application of each process Vacuum induction melting (VIM), Vacuum arc remelting (VAR), VIM, electroslag remelting (ESR),VIM, ESR, VAR.	3	CO2 CO3
2.5	Freckles, conditions of freckles, three rings, white spot- Super alloy cleanliness: ways and means to improve super alloy cleanliness, advantages of improved cleanliness, homogenization oxide cleanliness. (ASM).	2	CO3
3.1	Superalloys:- metallurgy of superalloys, superalloy characteristics - applications - service temperatures for superalloys.	1	CO2

3.2	Wrought superalloys, cast superalloys, properties of superalloys, mechanical properties and the application of superalloys, selecting superalloys.	1	CO2
3.3	Crystal structures, phases in superalloys, Iron-Nickel-base superalloys, Nickel-base superalloys, Cobalt-base superalloys, alloy elements and microstructural effects in superalloys, elements causing brittle phase formation, detrimental tramp elements, elements producing oxidation and hot corrosion resistance.	3	CO2
3.4	Microstructure, gamma prime, gamma double prime, Carbide and Boride phases, strengthening mechanisms: precipitate, gamma prime, gamma double prime, Carbides, M7C3 Carbides, Borides and other beneficial minor elements.	3	CO5
3.5	Heat treatment types:- stress relieving, annealing, quenching, precipitation, (ASM).	1	CO2
4.1	Single-crystal super alloys for blade applications:- directional solidification, heat transfer, formation of defects during directional solidification - mechanical behavior of the single-crystal super alloys, performance in creep, performance in fatigue (Reed).	3	CO4
4.2	Titanium: Ti-based binary phase diagram - production of ingot, Vacuum Arc Remelting - effect of forging temperature and forging pressure - closed die forgings - shear bands - pickling of titanium - Ti alloys - scrap recycling -problems in machining Titanium - welding of titanium - Heat Treatment of Ti - properties of titanium aluminides - applications.	4	CO2 CO5
4.3	Niobium: Production of niobium - niobium alloys - niobium in steel making – niobium alloys characteristics and applications- Niobium products for the superalloy industry.	2	CO2
5.1	Molybdenum: Ferromolybdenum - production of molybdenum – properties - effect of molybdenum alloying on hot strength, corrosion resistance, and toughness – applications - TZM, TZC.	2	CO2
5.2	Maraging steel:- Maraging steel chronology - reaction in austenite - austenite to martensite transformation- reaction in martensite - time of maraging - precipitate size - fracture toughness - welding and ageing attributes - superior features - applications - cobalt free maraging steel and comparisons.	4	CO2 CO4
5.3	Intermetallics:- Electronegativity, characteristics, property prediction - phase diagrams:- Magnesium - Lead, Copper – Zinc, Nickel -Titanium phase diagram - - The Hume-Rothery phases, electron phases /compounds, laves phases - Strukturbericht C15, C14, C36, etc - structures of $MgCu_2$, $MgZn_2$, $MgNi_2$.	3	CO2 CO4

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET 393	EXPERIMENTAL STRESS ANALYSIS	VAC	3	1	0	4

Preamble:

The course imparts to the students, the basic aspects of theory of elasticity and stress-strain relationship as well as experimental stress analysis that includes the most versatile techniques like photo elasticity, strain gauges and non-destructive test (NDT) methods.

Course Outcomes:

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

CO 1 Analyse the stresses, strains and deformations of structures under 2- and 3-dimensional loading by tensorial and graphical (Mohr's circle) approaches

CO 2 Describe the different instrument used for strain measurement materials using stress-strain relationships.

CO 3 Explain the concept behind the measurement and instrumentation.

CO 4 Describe the concept behind Photo elasticity and brittle coating.

CO 5 Describe the different NDT methods to evaluate the strength.

Mapping of course outcomes with program outcomes assessment Pattern

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3	2	1								1
CO 2	3	3	1	1								1
CO 3	3	2	1	1								1
CO 4	3	2	1	1								1
CO 5	3	1	1	1								1

Assessment Pattern

Blooms Category	Continuous Assessment Tests		ESE
	1	2	
Remember			
Understand	40	40	80
Apply		10	10
Analyse	10		10
Evaluate			
Create			

Mark Distribution

Total Marks	CIE	ESE	ESE Duration	
150	**50**	**100**	**3 Hrs**	

Continuous Internal Evaluation Pattern

Attendance	10
Continuous Assessment Tests (2 nos)	25
Assignments/ Quiz/ Course Project	15

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

COURSE LEVEL ASSESSMENT QUESTIONS

Course Outcome 1 (CO1): Analyse the stresses, strains and deformations of structures under 2- and 3-dimensional loading by tensorial and graphical (Mohr's circle) approaches.

1. Determine the resultant traction at a point in a plane using the stress tensor.
2. Evaluate the principal stresses, principal strains and their directions from a given state of stress or strain.
3. Write the stress tensor and strain tensor.

Course Outcome 2 (CO2): Describe the different instrument used for strain measurement materials using stress-strain relationships.

1. With help of fig, explain the construction and working of any one type of strain gauge.
2. Explain how strain can be measured over a long time at high and low temperature.
3. Explain how the delta rosette can be used for analysing the strain.

Course Outcome 3 (CO3): Describe the concept behind the measurement and instrumentation.

1. Describe Range and Sensitivity of a circuit
2. Define error, accuracy and precision with respect to measuring instrument.
3. With help of fig, Describe any one type of displacement measuring transducer.

Course Outcome 4 (CO4): Describe the concept behind Photo elasticity and brittle Coating.

1. Enumerate different steps involved in brittle coating.
2. Describe the effect of stressed model in plane polariscope.
3. Describe compensation techniques in photo elasticity.

Course Outcome 5 (CO5): Describe the different NDT methods to evaluate the strength.

1. Describe dye penetrant test with help of figure.
2. Explain penetrameter with help of figure.
3. With help of figure, explain Magnetic particle test.

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIFTH SEMESTER B.TECH DEGREE EXAMINATION

MET 393 EXPERIMENTAL STRESS ANALYSIS

Max. Marks:100 Duration: 3Hours

PART – A
(*ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS*)

1. Define stress at a point.
2. Explain principal stresses and strain.
3. How static and dynamic strain can be measured over a strain circuits.
4. What are residual stresses? What are its beneficial and harmful effects?
5. What are transducers? What are its properties?
6. Explain the different principles of measurements
7. Define stress optic law
8. What are the main uses of photo elastic coatings?
9. Distinguish between Destructive testing and Non-destructive testing.
10. What are the properties of X rays and Gamma rays.

PART – B
(*ANSWER ONE FULL QUESTION FROM EACH MODULE*)

MODULE – 1

11. The state of stress at a point is given by the Cartesian stress tensor $\begin{matrix} 3 & -1 & 1 \\ -1 & 5 & -1 \\ 1 & -1 & 3 \end{matrix}$ Kpa. Find (a) the stress invariant (b) characteristic equation (c) Principal stresses (d) Unit normal of the principal planes. (14marks)

12. a) Derive the expression for Cauchy's equation for stress on a given plane, normal stress & shear stress. (7marks)

b) Derive stress compatibility equation of plane strain problems. (7marks)

MODULE – 2

13. a) With help of neat sketch, explain a mechanical strain gauge (7 marks)

b) Explain how rectangular rosette can be analyzed for strain measurement. (7 marks)

14. a) With help of fig, explain a optical strain gauge. (7 Marks)

b) Describe how strain can be measured over a long period at low and high temperature. (7 marks)

MODULE – 3

15. a) with help of figure, explain the working of cathode ray oscilloscope. (7 marks)

b) With help of fig, explain the working of displacement transducer. (7 marks)

16. a) Prove that constant current potentiometer circuit has more sensitivity than that of a constant voltage circuit (7 marks)

b) With help of fig, explain the working of force transducer. (7 marks)

MODULE – 4

17 a) Describe the different types of available brittle coatings. (7marks)

b) Obtain the expression for intensity of light emerging from a plane polariscope with dark field set up. (7marks)

18 a) With help of fig, explain Tardy's method of compensation. (10 marks)

b) Explain isochromatic and isoclinics fringe pattern (4 marks)

MODULE – 5

19. a) Explain laser testing methods in NDT. (7 marks)

b) With help of fig, explain the steps involved in LPI. (7 marks)

20. a) With help of fig, explain Radiography test. (7 marks)

b) Explain the working of X – ray fluoroscopy (7 marks)

SYLLABUS

Module 1: Analysis of deformable bodies: stress, stress at a point using Cartesian stress tensor, Cauchy's equation for stress on a given plane, normal stress & shear stress; Strain, deformation and displacement (in Cartesian coordinates), strain components, 2D plane stress and plane strain problems, principal stresses (2D & 3D), stress invariants, Mohr's circle representation for stress in 2D and problems, representation 3D stress in Mohr's circle using principal stresses as input.

Module 2: Strain measurements: strain gauges and stress gauges. Mechanical, optical and electrical gauges – Construction and applications. Variable resistance strain gauges, gauge characteristics, gauge sensitivity, static and dynamic strain – strain measurement over a long period at low and high temperature. Strain rosettes – Rectangular rosettes, Delta rosettes. Residual stresses : Beneficial and harmful effects.

Module 3: Instrumentation: Strain circuits, potentiometer circuits, Range and sensitivity, The wheatstones bridge, sensitivity, Galvanometer, Transient response, Principles of measurements: Error, Accuracy and precision , Uncertainty analysis, Curve fitting. Oscillograph, cathode ray oscilloscope, Transducers – Displacement, Force, Pressure, velocity and acceleration.

Module 4: Photo elasticity: The polariscope, Stress optic law, Polariscope arrangements – Plane polariscope and Circular Polariscope. Dark field and light field, isochromatic and isoclinics, Use of photo elastic coatings, compensation techniques.
Brittle coatings: Coating stresses, Failure theories, steps in brittle coating tests.

Module 5: Non Destructive testing Methods – Types – dye penetrant methods, Radiography – X – ray and Gamma ray – X – ray fluoroscopy. Penetrameter – Magnetic particle methods. Introduction to lasers in NDT – Ultrasonic flaw detection.

Text Books

1. J. W. Dally and W. F. Riley, Experimental Stress Analysis - McGraw Hill, 1991
2. L.S. Srinath, M.R. Raghavan, K. Lingaiah, G. Gargesa, B. Pant, and K. Ramachandra, Experimental Stress Analysis, Tata Mc Graw Hill, 1984.
3. A. Mubin, Experimental Stress Analysis, Khanna Publishers, 2003.
4. Sadhu Singh, Experimental Stress Analysis, Khanna Publishers, 1996.

Reference Books

1. M. Hetenyi, Handbook of Experimental Stress Analysis, John Wiley & Sons Inc, New York, 1950
2. C.C. Perry and H.R. Lissener, Strain Gauge Primer, McGraw Hill, 2nd Ed., 1962.

3. W.J. McGonnagle-Non-destructive Testing-Mc Graw Hill, 1961.

COURSE PLAN

No	Topic	No. of Lectures
1	**Module 1: Stress and Strain Analysis**	**9 hrs**
1.1	Describe the deformation behaviour of elastic solids in equilibrium under the action of a system of forces. Describe method of sections to illustrate stress as resisting force per unit area. Stress vectors on Cartesian coordinate planes passing through a point .	1 hr
1.2	Direction cosines of a plane. Equality of cross shear (Derivation not required). Write Cauchy's equation (Derivation not required) for stress on a plane as the product of stress tensor and direction cosine vector. Normal and tangential (shear) components of stress on a plane.	1 hr
1.3	Deformation, displacement, gradient of deformation and strains in elastic solids. Cartesian components of strain and Cauchy's strain-displacement relationships (small-strain only). Strain tensor in 2D and 3D. Write the stress tensor and strain tensor for Plane stress and Plane Strain analysis.	1 hr
1.4	Stress on an oblique plane under axial loading, Discuss principal planes, characteristic equation to find principal stresses for 2D and 3D state of stress, stress invariants. Evaluate principal stresses in 2D and 3D using characteristic equations.	2 hrs
1.5	Discuss the order of principal stress and maximum shear stress. Compare the principal stresses in 2D and 3D state of stress. Represent the state of stress using principal stress tensor. Determine the direction of principal stresses as eigenvectors of the principal stress tensor.	2 hrs
1.6	Represent the 2D and 3D state of stress using principal stress graphically (Mohr's circle). Determine the maximum shear stress by Mohr's circle method and compare with the theoretical relations.	2 hrs
2	**Module 2: Strain measurements**	**8 hrs**
2.1	Strain gauges and stress gauges, Different types of strain gauges – construction and working, Different application of strain gauges. Variable resistance strain gauge	2 hr
2.2	Gauge characteristics, gauge sensitivity, measurement of static and dynamic strain, and measurement of strain over a long period at high and low temperature.	2 hrs
2.3	Strain rosette - Rectangular rosettes and Delta rosettes (simple problems).	2 hrs
2.4	Residual stresses, harmful effects of residual stresses, beneficial effects of residual stresses.	2 hrs
3	**Module 3 :Instrumentation**	**9 hrs**
3.1	Strain circuits, potentiometer circuits, Range and sensitivity, The wheatstones bridge.	2 hrs
3.2	Principles of measurements: Error, Accuracy and precision,	1 hr

	Uncertainty analysis, Curve fitting.	
3.3	Oscillograph ,cathode ray oscilloscope,	1 hr
3.4	Transducer – Characteristics and properties.	1 hr
3.5	Displacement transducer – Construction and working, Pressure transducer - Construction and working.	2 hrs
3.6	Velocity transducer - Construction and working	1 hr
3.7	Acceleration transducer - Construction and working.	1 hr
4	**Module 4 : Photoelasticity.**	**8 hrs**
4.1	The polariscope, Stress optic law, Polariscope arrangements – Plane polariscope and Circular Polariscope.	2 hrs
4.2	Dark field and light field , isochromatics and isoclinics , Use of photoelastic coatings.	2 hrs
4.3	Different types of compensation techniques.	2 hrs
4.4	Coating stresses, Failure theories, steps in brittle coating tests.	2 hr
5	**Module 5 :Non Destructive Methods.**	**8 hrs**
5.1	Non Destructive testing Methods – Types – dye penetrant methods, Radiography – X – ray and Gamma ray.	2 hrs
5.2	X – ray fluoroscopy , Penetrameter (Detailed description)	2 hr
5.3	Magnetic particle methods, advantages and disadvantages, applications.	2 hrs
5.4	Introduction to lasers in NDT – Ultrasonic flaw detection.	2 hrs

CODE MET394	COURSE NAME ADVANCED DESIGN SYNTHESIS	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble:

- To give an overview of the techniques used in Mechanical Engineering for the analysis and synthesis of Mechanisms.
- To familiarize the graphical and analytical techniques commonly used in the synthesis of mechanisms.
- To provide sufficient theoretical background to understand contemporary mechanism design techniques.
- To develop skills for applying these theories in practice. Identify mechanisms by type of motion (Planar, Spatial etc.)
- Select the best type of mechanism for a specific application and apply the fundamental synthesis technique to properly dimension the mechanism

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

CO 1	Analyse Velocity and Acceleration Analysis of complex mechanisms using auxiliary points
CO 2	Solve the synthesis of slider crank mechanism with three accuracy points
CO 3	Explain the synthesis of slider crank mechanism with four accuracy points
CO 4	Describe the algebraic methods of synthesis using displacement equations
CO 5	Demonstrate the algebraic methods of synthesis using complex numbers

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3	2									
CO 2	3	3	2									
CO 3	3	3	2									
CO 4	3	3	2									
CO 5	3	3	2									

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Calculate Velocity and Acceleration Analysis of complex mechanisms using auxiliary points.

2. Describe Roberts – Chebyshev theorem.

3. Explain the Inflection circle, Euler- Savery equation, and Hartman construction.

Course Outcome 2 (CO2)

1. Describe about the Relative poles of four bar linkages and slider crank mechanism.

2. List out the usage of Function generators.

3. Execute the synthesis of slider crank mechanism with three accuracy points.

Course Outcome 3(CO3):

1. Execute the geometric methods of synthesis with four accuracy points.

2. Discuss about the Construction of circle points, Cardinal points, opposite poles, and Pole quadrilaterals

3. Do the synthesis of slider crank mechanism with four accuracy points.

Course Outcome 4 (CO4):

1. Demonstrate the algebraic methods of synthesis using displacement equations.

2. Execute the Crank and follower synthesis.

3. Describe the method to get angular velocities and accelerations from crank and follower synthesis.

Course Outcome 5 (CO5):

1. Discuss about the Algebraic methods of synthesis using complex numbers.

2. Explain the importance Spatial motion and spatial linkages.

3. Demonstrate working of the Simple mechanisms in Robots.

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B. TECH DEGREE EXAMINATION
Course Code: MET394

Course Name: ADVANCED DESIGN SYNTHESIS
Max. Marks: 100
Duration: 3 Hours

PART – A

(ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS)

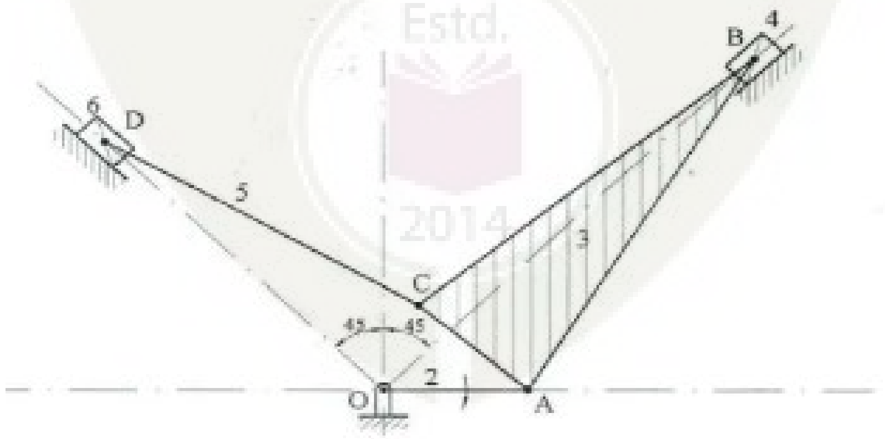
1. State and explain Robert Chebychev theorem?
2. Explain the properties of inflection circle?
3. What are three accuracy points in cam and follower synthesis?
4. Explain the relative poles of slider crank mechanism with sketch?
5. What is the significance function generator in the design of a mechanism?
6. Explain pole quadrilateral in geometric synthesis?
7. Define center point and circle point?
8. Write notes on types of errors in synthesis?
9. Draw a simple robot mechanism?
10. Classify the various types of spatial mechanisms?

PART – B

(ANSWER ONE FULL QUESTION FROM EACH MODULE)

MODULE – 1

11. For the twin cylinder V engine, determine the velocity of pistons B and D and the angular velocity of link 3. Link 2 rotates at 2000rpm. The dimensions of the various links are: O2A = 50mm ; AB = BC = 150mm ; AC =50mm ; CD = 125mm



(14 marks)

12. 12. Using overlay method and Chebychev spacing design a four-bar mechanism to generate the function $y = x^{1.5}$ for $0.5 < x < 1.5$. Assume six precision points. (14 marks)

Module 2

13. a) Discuss the significance of transmission angle in the design of a four-bar mechanism. (6 marks)

b) Explain the procedure for design of a four-bar mechanism for optimum transmission angle.

(8 marks)

14. Design a function generator linkage to solve y = 1/x in the range 1 < x < 2 using three precision points using geometric method. $\Delta\Phi = 90^o$, $\Delta\Psi = 90^o$, $\Phi_0 = 90^o$, $\Psi_0 = 45^o$. Plot a curve of the desire function and the one generated by the synthesized linkage and find the maximum error percentage. (14marks)

Module 3

15. Design a slider crank mechanism such that $\Phi_{12} = 30^o$ and $\Phi_{23} = 50_o$ and S_{12} = 25 cm and S_{23} = 20 cm using geometric method. The input crank moves in clockwise direction and the slider moves away from the crank pivot. (14 marks)

16. Design a double rocker mechanism to generate the function $y = e^x$ in the range $1 \le x \le 1$ using four precision points and Chebychev spacing using geometric method. (14 marks)

Module 4

17. Synthesize a four-bar generator to generate the function $y = \log_{10} x$ in the range $1 \le x \le 2$ using algebraic method. Assume suitable starting angles and ending angles for motion of input and output links. Use three precision points and Chebychev spacing. Find out the maximum error. (14marks)

18. Synthesize a four-bar linkage to meet the following specification of position, velocity and acceleration

$\Phi = 60^o$ $\Psi = 90^o$

ω_Φ = 5 rad/s ω_Ψ = 2 rad/s

α_Φ = 2 rad/s2 α_Ψ = 7 rad/s2 (14 marks)

Module 5

19. Synthesize a four-bar linkage to satisfy the following specifications:

ω_2 = 200 rad/s, ω3 = 85 rad/s, ω_4 = 130rad/s

α_2 = 0 rad/s^2, α3 = -1000 rad/s^2, α_4 = -1600 rad/s^2 (14 marks)

20. Compute the link lengths of a four-bar mechanism that will in one of its positions satisfy the following specifications: ω_1 = 8 rad/sec, α_1 = 0, ω_2 = 1 rad/sec, α_2 = 20 rad/sec^2, ω_3 = -3 rad/sec, α_3 = 0. (14 marks)

Syllabus

Module 1

Floating Link, Special methods of velocity and acceleration analysis using auxiliary points.Overlay method for conditioned crank mechanisms, coupler curves.

Roberts – Chebyshev theorem. Inflection circle, Euler- Savery equation, Hartman construction, Bobillier construction.

Module 2

Synthesis using Optimum transmission angle.

Geometric methods of synthesis with three accuracy points: - poles of four bar linkages, Relative poles of four bar linkages, Function generators, poles of slider crank mechanisms, Relative poles of slider crank Mechanisms, Rectilinear recorder mechanisms.

Synthesis of slider crank mechanism with three accuracy points.

Module 3

Geometric methods of synthesis with four accuracy points: - pole triangles, center point curves, Circle point curves, Construction of circle points, Cardinal points, opposite poles, Pole quadrilaterals,

Function Generators, Synthesis of slider crank mechanism with four accuracy points.

Module 4

Algebraic methods of synthesis using displacement equations: - Crank and follower synthesis- three accuracy points.

Crank and follower synthesis- angular velocities and accelerations.

Module 5

Rectilinear mechanisms, Algebraic methods of synthesis using complex numbers. Spatial motion and spatial linkages. Types of spatial mechanisms, Single loop linkage and multiple loop linkages. Simple mechanisms in robots.

Text Books

1. Kinematic synthesis of Linkages by Richard.S.Hartenberg, Jacques Denavit, McGraw Hill book company. 1964

2. Kinematics and linkage design by Allen.S.Hall. Prentice Hall of India, Ltd. 1986

3. Theory of Mechanisms and Machines by Shigley, McGraw Hill International Edition., 4th edition, 2014

4. Dynamics of Machinery by A.R.Holowenko. John Wiley & Sons Inc, 1955

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Floating Link, Special methods of Velocity and Acceleration Analysis using auxiliary points.	3
1.2	Overlay method for conditioned crank mechanisms, coupler curves. Roberts – Chebyshev theorem	3
1.3	Inflection circle, Euler- Savery equation, Hartman construction, Bobillier construction. Synthesis using Optimum transmission angle	3
2	**Module 2**	
2.1	Geometric methods of synthesis with three accuracy points: - poles of four bar linkages, Relative poles of four bar linkages,	3
2.2	Function generators, poles of slider crank mechanisms, Relative poles of slider crank Mechanisms, Rectilinear recorder mechanisms.	3
2.3	Synthesis of slider crank mechanism with three accuracy points.	3
3	**Module 3**	
3.1	Geometric methods of synthesis with four accuracy points: - pole triangles, center point curves,	3
3.2	Circle point curves, Construction of circle points, Cardinal points, opposite poles, Pole quadrilaterals,	3
3.3	Function Generators, Synthesis of slider crank mechanism with four accuracy points.	3
4	**Module 4**	
4.1	Algebraic methods of synthesis using displacement equations: - Crank and follower synthesis- three accuracy points	4
4.2	Crank and follower synthesis- angular velocities and accelerations	4
5	**Module 5**	
5.1	Rectilinear mechanisms, Algebraic methods of synthesis using complex numbers.	3
5.2	Spatial motion and spatial linkages	3
5.3	Types of spatial mechanisms, Single loop linkage and multiple loop linkages. Simple mechanisms in Robots.	3

CODE MET395	COURSE NAME ADVANCED THERMODYNAMICS	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: This course involves the application of principles studied in thermodynamics for analysis of thermal energy systems. This course also covers the properties of pure substances, Energy balance of reacting systems and advances in chemical thermodynamics.

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

CO 1	Apply the concepts of basic thermodynamics, entropy and energy for analyses of thermal energy systems.
CO 2	Understand properties of pure substance and thermodynamic properties of real gases
CO 3	Apply energy balances to reacting systems for both closed and open system.
CO 4	Define the chemical equilibrium constant and apply the general criteria for chemical equilibrium analysis to reacting ideal-gas mixtures.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	**3**	3	2									
CO 2	**3**	3	2									
CO 3	**3**	3	2									
CO 4	**3**	3	2									

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	10	10	20
Apply	20	20	50
Analyse	10	10	20
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. One kg of water at 273 K is brought into contact with a heat reservoir at 373 K. When the water has reached 373 K , find the entropy change of water, of the heat reservoir and of the universe.
2. State and prove Clausius Theorem
3. Water at 363 K flowing at the rate of 2 kg/s mixes adiabatically with another stream of water at 303 K flowing at the rate of 1 kg/s. Estimate the entropy generation rate and rate of exergy loss due to mixing. Take T_0 = 300 K

Course Outcome 2 (CO2)

1. A large insulated vessel is divided into two chambers one containing 5 kg of dry saturated steam at 0.2 MPa and the other 10 Kg of steam 0.8 quality at 0.5 MPa. If the partition between the chambers is removed and the steam is mixed thoroughly and allowed to settle, find the final pressure , steam quality and entropy change in the process
2. Draw the phase equilibrium diagram for a pure substance on h-s plot with relevant constant property lines.
3. Show that for an ideal gas the slope of the constant volume line on the T-S diagram is more than that of the constant pressure line.

Course Outcome 3(CO3):

1. Determine the adiabatic flame temperature when liquid octane at 298 K is burned with 300% theoretical air at 298 K in a steady flow process
2. What is heat of reaction? When is it positive and when negative?

3. Calculate the degree of ionization of cesium vapour at 10^{-6} atm at the two temperatures of 2260 and 2520 K

Course Outcome 4 (CO4):

1. Explain law of mass action
2. Explain reaction equilibrium constant.
3. Discuss second law analysis of reactive systems

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

V SEMESTER BTECH DEGREE EXAMINATION

MET395: ADVANCED THERMODYNAMICS

Maximum: 100Marks Duration:3 hours

PART A

Answer all questions, each question carries 3 marks

1. Show that entropy is a property of the system
2. What is the meaning of quality of energy
3. Draw the phase equilibrium diagram for a pure substance on T-s plot with relevant constant property lines.
4. Write Clausius – Clapeyron equations
5. Explain law of corresponding states
6. Explain Wander-Walls equation of state
7. Explain Second-Law Analysis of Reacting systems
8. What do you meant by adiabatic flame temperature?
9. Explain law of mass action
10. What is van’t Hoff equation

(10×3=30Marks)

PART B

Answer one full question from each module

MODULE 1

11. Three identical finite bodies of constant heat capacity are at temperatures 300, 300 and 100 K. If no work or heat is supplied from outside, what is the highest temperature to which any one of the bodies can be raised by the operation of heat engines or refrigerators (14 marks)

12. A pressure vessel has a volume of 1m3 and contains air at 1.4 MPa, 448K. The air is cooled to 298K by heat transfer to surroundings at 298 K. Calculate the availability in the initial and final states and irreversibility of the process. Take P0 = 100kPa (14 marks)

MODULE 2

13. Steam initially at 0.3 MPa, 523K is cooled at constant volume. Find

a) Temperature at which steam become saturated vapour,

b) What is the quality at 353 K,

c) What is the heat transferred per kg of steam in cooling from 523 K to 353 K

(14 marks)

14. Derive Maxwell relations and TdS equations (14 marks)

MODULE 3

15. a) What are virial coefficients ? When do they become zero? (7 Marks)

b) Express Wander – Walls constants in terms of critical properties (7 marks)

16. Calculate the volume of 2.5 Kg moles of steam at 236.4 atm. And 776.76 K with the help of compressibility factor vs reduced pressure graph. At this given volume and pressure what would be the temperature in K, if steam behaves like a Vander-Walls gas. The critical pressure, volume and temperature of steam are 218.2 atm, 57 cm3/g mole and 647.3 K respectively.

(14 marks)

MODULE 4

17. a) Explain second law efficiency of a reactive system ? (4 marks)

b) Explain first law analysis of reactive systems. (10 Marks)

18. The products of combustion of an unknown hydrocarbon CxHy have the following composition a measured by an Orsat apparatus

CO_2 8%, CO 0.9%, O_2 8.8% and N_2 82.3 % Find a) Composition fuel b) air-fuel ratio and c) percentage of excess air used. (14 marks)

MODULE 5

19. a) What is Gibbs function of formation (5 marks)

b) Explain the phase equilibrium for a single component system

(9 marks)

20. a) What is degree of reaction (5 marks)

b) Explain the phase equilibrium for a multi component system (9 marks)

Syllabus

Module 1

RECAPITULATION OF FUNDAMENTALS. Basic definition and concepts; The basic laws of Thermodynamics, Entropy flow and entropy production, 3rd law of Thermodynamics, Availability in steady flow open system and in a closed system, Irreversibility and effectiveness.

Module 2

PROPERTIES OF PURE SUBSTANCES. P-V-T surfaces, phase diagram, phase changes, various properties diagram, 1st order phase transition and 2nd order phase transition, Clapeyron's equation, Ehrenfest's equations, Maxwell's equations, equation for internal energy, enthalpy, entropy, specific heat and joule Thompson coefficient.

Module 3

EQUATION OF STATE FOR REAL GASES. Compressibility factor and generalised compressibility chart, Law of corresponding state, law of pseudo critical pressure and temperature, reduced coordinate, Wander-Walls equation of state and other equation of state.

Module 4

CHEMICAL REACTION. Fuels and Combustion, First-Law Analysis of Reacting Systems: Steady-Flow Systems and Closed Systems, Entropy Change of Reacting Systems, Second-Law Analysis of Reacting systems.

Module 5

CHEMICAL THERMODYNAMICS. Gibb's theorem, Gibbs function of mixture of inert ideal gases, Chemical equilibrium, Thermodynamic equation for phase, Degree of reaction, equation of reaction, law of mass action, heat of reaction and Vant Hoff Isober, Phase Equilibrium for a Single-Component System and Multi-Component System

Text books:

1. Richard Edwin Sonntag , G.J. Van Wylen, Introduction to Thermodynamics- Classical and Statistical Wiley , 1991

2. Cengel and Boles.,Thermodynamics : An engineering Approach McGraw-Hill, 2007 Sixth Edition

3. P.K. Nag. Engineering Thermodynamics Tata McGraw -Hill , 2013

Reference books:

1. M. Zemansky, R H Dittman. Heat and Thermodymics –7th Edition 1998

2. E. F . Obert, Concepts of thermodynamics – McGraw-Hill, 1963

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1		
1.1	Basic definition and concepts; The basic laws of Thermodynamics,	3
1.2	Entropy flow and entropy production, 3rd law of Thermodynamics,	2
1.3	Availability in steady flow open system and in a closed system	2
1.4	Irreversibility and effectiveness.	2
2		
2.1	PROPERTIES OF PURE SUBSTANCES. P-V-T surfaces, phase diagram, phase changes, various properties diagram,	3
2.2	1st order phase transition and 2nd order phase transition, Clapeyron's equation, Ehrenfest's equations,	3
2.3	Maxwell's equations, equation for internal energy, enthalpy, entropy, specific heat and joule Thompson coefficient.	3
3		
3.1	EQUATION OF STATE FOR REAL GASES. Compressibility factor and generalised compressibility chart,	2
3.2	Law of corresponding state	2
3.3	law of pseudo critical pressure and temperature	3
3.4	Reduced coordinate, Wander-Walls equation of state and other equation of state.	2
4		
4.1	CHEMICAL REACTION. Fuels and Combustion,	1
4.2	First-Law Analysis of Reacting Systems: Steady-Flow Systems and Closed Systems	3
4.3	Entropy Change of Reacting Systems	2
4.4	Second-Law Analysis of Reacting systems	3
5		
5.1	CHEMICAL THERMODYNAMICS. Gibb's theorem, Gibbs function of mixture of inert ideal gases,	2
5.2	Chemical equilibrium, Thermodynamic equation for phase,	2
5.3	Degree of reaction, equation of reaction, law of mass action,	2
5.4	Heat of reaction and Vant Hoff Isober, Phase Equilibrium for a Single-Component System and Multi-Component System	3

CODE	COURSENAME	CATEGORY	L-T-P	CREDITS
MET 397	FLUID POWER AUTOMATION	VAC	3-1-0	4

Preamble :
This course provides basic ideas of fluid power automation. It enables the students to design and optimize pneumatic and hydraulic automation systems.

Prerequisite : Nil

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

CO1	Explain the concept of power generating elements
CO2	Describe fundamentals of actuator and accumulator
CO3	Explain in detail control and regulation elements
CO4	Illustrate different circuit design methods
CO5	Illustrate electrical control of pneumatic and hydraulics circuits

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	1									
CO2	3	2										
CO3	3	2	1									
CO4	3	1										
CO5	3	1										

Assessment Pattern

Bloom Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark Distribution and duration of ESE

Total Marks	CA	ESE	ESE Duration
150	50	100	3 Hours

Continuous Internal Evaluation Pattern

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End semester pattern:

There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions:

Course Outcome 1 (CO1):

1. Explain the need and benefits of automation.
2. Discuss the various components of a fluid power system.
3. Discuss about the hydraulic and pneumatic element selection criteria based with respect to a typical example.

Course Outcome 2 (CO2):

1. Write a detailed note on Linear Actuators.
2. Give a short notes on (a) Spring Return Single acting Cylinder and (b) Double acting cylinder with a piston rod on both sides
3. Make a circuit sketch showing the use of accumulators as a shock absorber.

Course Outcome 3 (CO3):

1. Explain different types of direction and flow control valves.
2. Explain the components of closed loop hydraulic systems with a block diagram.
3. With a neat sketch, describe the construction and working of pressure compensated flow control valve.

Course Outcome 4 (CO4):

1. Construct a ladder diagram for a hydraulic circuit with six cylinders used to control industrial robot.
2. Describe combinational and sequential logical circuits.
3. Design and develop a hydraulic circuit for the following sequence using cascade method. A+ B+ C+

Course Outcome 5 (CO5):

1. Explain basic electrical devices used in electro pneumatic circuits.
2. Explain the functions of relays, timers andcounters in hydraulic and pneumatic circuits.
3. Explain the basic structure of a PLC.

MODEL QUESTION PAPER
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
V SEMESTER B.TECH DEGREE EXAMINATION
MET397: FLUID POWER AUTOMATION

Maximum: 100 Marks **Duration: 3 hours**

PART A

Answer all questions, each question carries 3 marks

1. What are the limitations of fluid power automation?
2. What are the factors to be considered in the selection of pump?
3. Define spool valve?
4. How is counter represented in ladder diagram?
5. What is a linear actuator?
6. What is the function Karnaugh map?
7. Define underlap and overlap in the context of servo valve spools?
8. What are the uses of relays in hydraulic and pneumatic circuits?
9. What is the function of intensifier?
10. List the components of PLC. (10 X 3 = 30 marks)

PART B

Answer one full question from each module

Module 1

11. Describe in brief with neat sketches any 16 ISO symbols used for fluid power elements. (14 marks)
12. Briefly explain the working and construction details of Vane pump with a diagram (14 marks)

Module 2

13. Describe the working principle of hydraulic accumulators (14 marks)
14. With a neat sketch, explain the end cushion provided in hydraulic cylinder (14 marks)

Module 3

15. Draw a neat sketch and explain the working of pressure and temperature compensated flow control valve (14 marks)
16. Write short notes on direction control valves and its types with neat sketches (14 marks)

Module 4

17. Draw and explain the working principle of fail-safe circuit with overload protection (14 marks)
18. Design and draw a hydraulic circuit for A+B+B+A+ sequencing operation and explain. (14marks)

Module 5

19. Design and draw electro hydraulic circuit for hydraulic motor braking system

(14 marks)

20. a) Draw the fluid power symbols of any 4 accessories (4 marks)
    b) Describe the advantages and disadvantages of fluid power systems

(10 marks)

Syllabus

Module 1

Need for automation, classification of drives- hydraulic and pneumatic –comparison ISO symbols for fluid power elements, selection criteria Fluid power generating elements-hydraulic pumps and motorgears, vane, piston pumps-motors-selection and specification

Module 2

Drive characteristics- linear actuator–types, mounting details, cushioning–power packs–accumulators

Module 3

Control and regulation elements—direction, flow and pressure control valves-methods of actuation, types, sizing of ports. Spool valves- operating characteristics, electro hydraulic servo valves-different types-characteristics and performance

Module 4

Typical design methods –ladder diagram- sequencing circuits design - combinational logic circuit design-cascade method - Karnaugh map method.

Module 5

Electrical control of pneumatic and hydraulic circuits- use of relays, timers, counters, interfacing with PLCs, proportional control of hydraulic systems

Text Books:

1. Alavudeen A, Fluid Power Transmission and Control, Charotar Publishing House, 2007
2. Jagadeesha T, Hydraulics and Pneumatics, I K International Publishing House, 2015
3. AntonyEsposito,FluidPowerSystemsandcontrol,Prentice-Hall,1988

Reference Books:

1. PeterRohner,FluidPowerlogiccircuitdesign, MacmillanPress, 1994.
2. E.C.FitchandJ.B.Surjaatmadja.Introductiontofluidlogic,McGrawHill, 1978
3. HerbertE.Merritt,Hydrauliccontrolsystems,JohnWiley&Sons,1967
4. Dudley.A.Pease,BasicFluidPower,PrenticeHall,1967

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
I	Need for automation, classification of drives- hydraulic and pneumatic – comparison, ISO symbols for fluid power elements, selection criteria	**4**
	Fluid power generating elements – hydraulic pumps and motorgears, vane, piston pumps-motors- selection and specification	**5**
II	Drive characteristics- linear actuator–types, mounting details, cushioning–power packs–accumulators	**9**
III	Control and regulation elements—direction, flow and pressure control valves- methods of actuation, types, sizing of ports, spool valves-operating characteristics, Electro hydraulic servo valves-different types-characteristics and performance	**10**
IV	Typical design methods –Ladder diagram- sequencing circuits design - combinational logic circuit design-cascade method – Karnaugh map method.	**9**
V	Electrical control of pneumatic and hydraulic circuits- use of relays, timers, counters ,interfacing with PLCs, proportional control of hydraulic systems	**8**

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET 396	COMPRESSIBLE FLUID FLOW	VAC	3	1	0	4

Preamble:

The objectives of the course are:

- To introduce the fundamental concepts involved in compressible flow.
- To apply the fundamental laws to one dimensional compressible isentropic flow for the design of convergent and divergent nozzles.
- To solve the problems of compressible flow in constant area duct involving friction and heat transfer.
- To understand the flow mechanism before and after the normal/oblique shocks
- To introduce various measurement and visualisation techniques in compressible flows.

Prerequisite: MET203 Mechanics of fluid, MET202 Engineering Thermodynamic

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

CO 1	Explain the fundamental concepts involved in compressible flow
CO 2	Formulate and solve typical problems in one dimensional isentropic compressible flow by use of the appropriate equations and tables.
CO 3	Solve typical problems of flow in constant area duct with friction
CO 4	Solve typical problems of flow in constant area duct with friction
CO 5	Calculate the change in flow properties across normal and oblique shock waves.
CO 6	Illustrate different techniques used in measurement and visualization of compressible flows

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3										2
CO 2	3	3	2	2								3
CO 3	3	2	2									1
CO 4	3	2	2	1								
CO 5	3	2										2
CO 6	3	3										

Assessment Pattern

Bloom's Category	Continuous Assessment			End Semester Examination
	Assignment (%)	Test 1 (%)	Test 2 (%)	
Remember	25	20	20	10
Understand	25	40	40	20
Apply	25	40	40	70
Analyse	25			
Evaluate				
Create				

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Represent various flow regimes on steady flow adiabatic ellipse.
2. List the various conservation laws governing the compressible flow
3. Define Mach cone and Mach Angle

Course Outcome 2 (CO2)

1. Express stagnation enthalpy in terms of static enthalpy and velocity of flow
2. Explain the phenomenon of choking in isentropic flow.
3. Write applications of convergent nozzles and convergent-Divergent nozzles

Course Outcome 3 (CO3):

1. Describe the phenomenon of frictional chocking
2. Differentiate between Fanno flow and Isothermal flow

3. Explain the significance of critical length in Fanno flow

Course Outcome 4 (CO4):

1. Explain the process of thermal chocking in Rayleigh flow
2. Under what conditions the assumptions of Rayleigh flow is not valid in a heat exchanger
3. Locate the maximum enthalpy point in Rayleigh flow

Course Outcome 5 (CO5):

1. State and prove Prandtl-Mayer relationship for a normal shock wave.
2. What is an expansion fan? How does it occur in supersonic flow?
3. Explain why shock is impossible in subsonic flow.

Course Outcome 6 (CO6):

1. Name the various types of wind tunnels used for low and high speed testing of models
2. Difference between working principle of Shadowgraph and Schlieren techniques
3. Explain the working principle of constant current hot wire anemometer

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SIXTH SEMESTER MECHANICAL ENGINEERING

Compressible Fluid Flow -MET396

Maximum: 100 Marks **Duration: 3 hours**

PART A

Answer all questions. Each question carries 3 marks

1. Derive an expression for stagnation temperature in terms of Mach number for compressible fluid flow.
2. Derive the condition at which flow become choked in isentropic flow?
3. Prove that Mach number is unity at the maximum entropy point on a Fanno curve.
4. Explain the significance of critical length in Fanno flow
5. What is Rayleigh flow? Explain Rayleigh flow with one practical case.
6. Under what conditions the assumptions of Rayleigh flow is not valid in a heat exchanger
7. Explain two situations where a normal shock wave is formed

8. Explain the formation of oblique shock wave in a concave corner and expansion fan in convex corner

9. Mention the difference in principle of the shadowgraph and Schlieren system

10. Explain with the help of sketches how yaw angle is eliminated in a Kiel probe.

(10 X 3 = 30 Marks)

PART B

Answer one full question from each module

MODULE 1

11.a. An air nozzle is to be designed for an exit Mach number of 2. conditions of the air available in the reservoir are 700 kPa, 533 K. Estimate i) pressure ii) temperature iii) velocity of flow iv) area, at throat and exit of the nozzle. Mass flow rate through the nozzle is 10000 kg/hr. 10 marks

b. Derive an expression for area ratio in terms of Mach number for isentropic flow. Explain graphically the variation of area ratio with Mach number. 4 marks

12.a. Derive the conservation of mass equation for compressible flow through control volume approach. 4 marks

b. A perfect gas having Cp = 1017.4 J/kg and molecular weight 28.97 flows adiabatically in a converging passage with a mass flow rate if 27.20kg/s. At a particular location, M = 0.5, T = 500K and p = 0.25 MPa. Calculate the area of cross section of the duct at the location.

10 marks

MODULE II

13.a. A circular duct passes 8.25 kg/s of air at an exit Mach number of 0.5. The entry pressure and temperature are 3.45 bar and 38^{o}C respectively and the mean coefficient of friction 0.005. If the Mach number at the entry is 0.15, determine i) diameter of the duct, ii) length of duct, iii) pressure and temperature at exit and iv) stagnation pressure loss. 8 marks

b. Differentiate between Fanno flow and isothermal flow. Give one practical example each for Fanno flow and isothermal flow. 6 marks

14.a. Explain the phenomenon of choking in Fanno flow. 4 marks

b. Air enters, a long circular duct of diameter 12 cm and mean coefficient of friction 0.0045, at a Mach number of 0.5, pressure 3.5 bar and temperature 300 K. If the flow is adiabatic throughout the duct, determine i) the length of the pipe required to change the Mach number to 0.6 ii) pressure and temperature of air at M=0.6 iii) the length of the pipe required to attain limiting Mach number iv) pressure, temperature and Mach number at the limiting condition 10 marks

MODULE III

15.a. Derive an equation describing a Rayleigh curve. Show that at maximum entropy point the flow is sonic. 6 marks

b. Data for entry of air at a constant area duct are p1 = 0.35 bar, T1 = 300 K, velocity of gas c1 = 60 m/s. If 620 kJ/kg if heat is added to the gas in the duct between entry and exit sections, determine at the exit i) pressure ii) temperature iii) Mach number iv) velocity of gas. How much heat is required to accelerate air from initial condition to sonic condition? 8 marks

16.a. Derive an expression for maximum possible heat transfer in Rayleigh flow in terms of Mach number. 7 marks

b. Air at Mach 1.5, pressure 300kPa and temperature 288K is brought to sonic velocity in a frictionless constant area duct through heat transfer. Determine the final pressure, temperature and heat added during the process. 7 marks

MODULE IV

17.a. Derive an expression for Mach number downstream of a normal shock 7 marks

b. The ratio of exit to entry area in a subsonic diffuser is 3.3. The Mach number of a jet of air approaching the diffuser is 2.1. Stagnation pressure of the jet is 1.1 bar and its static temperature is 330 K. There is a standing normal shock wave just outside the diffuser entry. The flow in the diffuser is isentropic. Determine pressure, temperature and Mach number at the exit of the diffuser. Also find the loss in stagnation pressure of the jet as it passes through the diffuser. 7 marks

18. a. What is an expansion fan? How does it occur in supersonic flow? 5 marks

18b. A stationary normal shock occurs in an air stream when the pressure, temperature and Mach number are 85 kPa, 110 ^{0}C and 1.7 respectively. Determine its density after the shock. Compare this value in an isentropic compression through the same pressure ratio. 9 marks

MODULE V

19 a. Explain the working of a shock tube with a neat sketch 8 marks

b. Explain the working of a constant current hot wire anemometer used for flow velocity measurement. 6 marks

20 a. Describe with the aid of a schematic diagram the working of a closed circuit supersonic wind tunnel. 7 marks

b. With a neat sketch explain the working of stagnation temperature probe. 7 marks

Syllabus

Module 1- FUNDAMENTALS OF COMPRESSIBLE FLOW & ISENTROPIC FLOW

Fundamentals of compressible flow: Concept of continuum-system and control volume approach-conservation of mass, momentum and energy- Mach number and its significance- Mach waves- Mach cone and Mach angle- physical difference between incompressible, subsonic, sonic and supersonic flows- static and stagnation states- relationship between stagnation temperature, pressure, density and enthalpy in terms of Mach number- Reference states in compressible fluid flows - adiabatic energy equation-representation of various flow regimes on steady flow adiabatic ellipse.

One Dimensional Isentropic flow: General features of isentropic flow- Comparison of adiabatic and isentropic process- One dimensional isentropic flow in ducts of varying cross-section- nozzles and diffusers- mass flow rate in nozzles- critical properties and choking- area ratio as function of Mach number- Impulse function- operation of nozzle under varying pressure ratios –over expansion and under expansion in nozzles-Applications of convergent divergent nozzles- Use of gas dynamics tables.

Module 2 FANNO FLOW

Flow in constant area duct with friction (Fanno flow): Fanno curve and Fanno flow equations - Fanno line on h-s and p-v diagram- variation of flow properties- variation of Mach number with duct length-Chocking due to friction- isothermal flow in constant area duct with friction- Use of gas dynamics tables.

Module 3 RAYLEIGH FLOW

Flow through constant area duct with heat transfer (Rayleigh Flow): Rayleigh line on h-s and p-v diagram-location of maximum enthalpy point- thermal chocking-and maximum heat transfer-variations of flow properties- Use of gas dynamics tables.

Module 4 NORMAL & OBLIQUE SHOCK WAVES

Normal shock Waves: Development of shock wave- governing equations- Strength of shock waves-Normal Shock on T-S diagram -Prandtl-Mayer relation, Rankine-Hugoniot relation- Mach number in the downstream of normal shock- variation of flow parameters across the normal shock -normal shock in Fanno and Rayleigh flows- working formula- curves and tables

Oblique shock waves: weak and strong oblique shocks-shock polar diagram-expansion waves-Reflection and intersection of oblique shocks and expansion waves

Module 5 MEASUREMENT & VISUALIZATION TECHNIQUES

Compressible flow field measurement & visualization - Shadowgraph- Schlieren technique-interferometer- subsonic and supersonic flow measurement (Pressure, Velocity and Temperature) – compressibility correction factor- hot wire anemometer- Rayleigh Pitot tube- wedge probe- stagnation temperature probe- temperature recovery factor –Kiel probe - Wind tunnels – closed and open type-sub sonic – supersonic wind tunnels – shock tube.

Text Books

1. Fundamentals of Compressible flow, S. M. Yahya, New age international Publication, Delhi

2. Fundamentals of compressible fluid dynamics- P. Balachandran, PHI Learning, New Delhi

4. Gas Dynamics, E. Rathakrishnan, PHI Learning Pvt. Ltd

5. Gas Dynamics and Jet Propulsion- P. Murugaperumal, Scitech Publication, Chennai.

Data Book

1. Yahya S. M., Gas Tables, New Age International.

2. Balachandran P., Gas Tables, Prentice-Hall of India Pvt. Limited.

Reference Books

1. The dynamics and thermodynamics of Compressible fluid flow Volume-I, Ascher H. Shapiro, the Ronald Press Company, New York.

2. Modern Compressible Flow: With Historical Perspective, John D. Anderson, McGraw-Hill Higher Education

COURSE PLAN

MODULE	TOPICS	HOURS ALLOTED
1	Concept of continuum-system and control volume approach- conservation of mass, momentum and energy	3-1-0
	Mach number and its significance- Mach waves- Mach cone and Mach angle- physical difference between incompressible, subsonic, sonic and supersonic flows- static and stagnation states- relationship between stagnation temperature, pressure, density and enthalpy in terms of Mach number- stagnation velocity of sound- adiabatic energy equation- representation of various flow regimes on steady flow adiabatic ellipse	2-1-0
	General features of isentropic flow- performance curve- Comparison of adiabatic and isentropic process- One dimensional isentropic flow in ducts of varying cross-section- nozzles and diffusers- mass flow rate in nozzles- critical properties and choking- area ratio as function of Mach number- Impulse function- operation of nozzle under varying pressure ratios –over expansion and under expansion in nozzles-Applications of convergent divergent nozzles-Working charts and gas tables.	4-1-0
2	Fanno curve and Fanno flow equations - Fanno line on h-s and P-v diagram- solution of Fanno flow equations- variation of flow properties- variation of Mach number with duct length- Chocking due to friction- tables and charts for Fanno flow- isothermal flow in constant area duct with friction.	4-2-0
	Flow through constant area duct with heat transfer (Rayleigh Flow): Simple heating relation of a perfect gas- Rayleigh line on h-s and P-v diagram-location of maximum enthalpy point- thermal chocking-and maximum heat transfer- variations of flow properties- tables and charts	

3	for Rayleigh flow.	**4-2-0**
4	Development of shock wave- Thickness of shock wave- governing equations- Strength of shock waves- Normal Shock on T-S diagram - Prandtl-Mayer relation, Rankine-Hugoniot relation- Mach number in the downstream of normal shock	**4-1-0**
	variation of flow parameters across the normal shock -normal shock in Fanno and Rayleigh flows- working formula- curves and tables	**2-1-0**
	weak and strong oblique shocks-shock polar diagram-expansion waves-Reflection and intersection of oblique shocks and expansion waves	**2-1-0**
5	Shadowgraph- Schlieren technique-interferometer	**2-0-0**
	subsonic and supersonic flow measurement (Pressure, Velocity and Temperature) – compressibility correction factor- hot wire anemometer-Rayleigh Pitot tube- wedge probe- stagnation temperature probe-temperature recovery factor –Kiel probe - Wind tunnels – closed and open type- sub sonic – supersonic wind tunnels – shock tube	**3-0-0**

CODE	COURSENAME	CATEGORY	L-T-P	CREDITS
MET 397	FLUID POWER AUTOMATION	VAC	3-1-0	4

Preamble :

This course provides basic ideas of fluid power automation. It enables the students to design and optimize pneumatic and hydraulic automation systems.

Prerequisite : Nil

Course Outcomes :

After completion of the course the student will be able to

CO1	Explain the concept of power generating elements
CO2	Describe fundamentals of actuator and accumulator
CO3	Explain in detail control and regulation elements
CO4	Illustrate different circuit design methods
CO5	Illustrate electrical control of pneumatic and hydraulics circuits

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	1									
CO2	3	2										
CO3	3	2	1									
CO4	3	1										
CO5	3	1										

Assessment Pattern

Bloom Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark Distribution and duration of ESE

Total Marks	CA	ESE	ESE Duration
150	50	100	3 Hours

Continuous Internal Evaluation Pattern

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End semester pattern:

There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions:

Course Outcome 1 (CO1):

1. Explain the need and benefits of automation.
2. Discuss the various components of a fluid power system.
3. Discuss about the hydraulic and pneumatic element selection criteria based with respect to a typical example.

Course Outcome 2 (CO2):

1. Write a detailed note on Linear Actuators.
2. Give a short notes on (a) Spring Return Single acting Cylinder and (b) Double acting cylinder with a piston rod on both sides
3. Make a circuit sketch showing the use of accumulators as a shock absorber.

Course Outcome 3 (CO3):

1. Explain different types of direction and flow control valves.
2. Explain the components of closed loop hydraulic systems with a block diagram.
3. With a neat sketch, describe the construction and working of pressure compensated flow control valve.

Course Outcome 4 (CO4):

1. Construct a ladder diagram for a hydraulic circuit with six cylinders used to control industrial robot.
2. Describe combinational and sequential logical circuits.
3. Design and develop a hydraulic circuit for the following sequence using cascade method. A+ B+ C+

Course Outcome 5 (CO5):

1. Explain basic electrical devices used in electro pneumatic circuits.
2. Explain the functions of relays, timers andcounters in hydraulic and pneumatic circuits.
3. Explain the basic structure of a PLC.

MODEL QUESTION PAPER
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
V SEMESTER B.TECH DEGREE EXAMINATION
MET397: FLUID POWER AUTOMATION

Maximum: 100 Marks **Duration: 3 hours**

PART A

Answer all questions, each question carries 3 marks

1. What are the limitations of fluid power automation?
2. What are the factors to be considered in the selection of pump?
3. Define spool valve?
4. How is counter represented in ladder diagram?
5. What is a linear actuator?
6. What is the function Karnaugh map?
7. Define underlap and overlap in the context of servo valve spools?
8. What are the uses of relays in hydraulic and pneumatic circuits?
9. What is the function of intensifier?
10. List the components of PLC. (10 X 3 = 30 marks)

PART B

Answer one full question from each module

Module 1

11. Describe in brief with neat sketches any 16 ISO symbols used for fluid power elements. (14 marks)
12. Briefly explain the working and construction details of Vane pump with a diagram (14 marks)

Module 2

13. Describe the working principle of hydraulic accumulators (14 marks)
14. With a neat sketch, explain the end cushion provided in hydraulic cylinder (14 marks)

Module 3

15. Draw a neat sketch and explain the working of pressure and temperature compensated flow control valve (14 marks)
16. Write short notes on direction control valves and its types with neat sketches (14 marks)

Module 4

17. Draw and explain the working principle of fail-safe circuit with overload protection (14 marks)
18. Design and draw a hydraulic circuit for A+B+B+A+ sequencing operation and explain. (14marks)

Module 5

19. Design and draw electro hydraulic circuit for hydraulic motor braking system

(14 marks)

20. a) Draw the fluid power symbols of any 4 accessories (4 marks)
b) Describe the advantages and disadvantages of fluid power systems

(10 marks)

Syllabus

Module 1

Need for automation, classification of drives- hydraulic and pneumatic –comparison ISO symbols for fluid power elements, selection criteria Fluid power generating elements-hydraulic pumps and motorgears, vane, piston pumps-motors-selection and specification

Module 2

Drive characteristics- linear actuator–types, mounting details, cushioning–power packs–accumulators

Module 3

Control and regulation elements—direction, flow and pressure control valves-methods of actuation, types, sizing of ports. Spool valves- operating characteristics, electro hydraulic servo valves-different types-characteristics and performance

Module 4

Typical design methods –ladder diagram- sequencing circuits design - combinational logic circuit design-cascade method - Karnaugh map method.

Module 5

Electrical control of pneumatic and hydraulic circuits- use of relays, timers, counters, interfacing with PLCs, proportional control of hydraulic systems

Text Books:

1. Alavudeen A, Fluid Power Transmission and Control, Charotar Publishing House, 2007
2. Jagadeesha T, Hydraulics and Pneumatics, I K International Publishing House, 2015
3. AntonyEsposito,FluidPowerSystemsandcontrol,Prentice-Hall,1988

Reference Books:

1. PeterRohner,FluidPowerlogiccircuitdesign, MacmillanPress, 1994.
2. E.C.FitchandJ.B.Surjaatmadja.Introductiontofluidlogic,McGrawHill, 1978
3. HerbertE.Merritt,Hydrauliccontrolsystems,JohnWiley&Sons,1967
4. Dudley.A.Pease,BasicFluidPower,PrenticeHall,1967

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
I	Need for automation, classification of drives- hydraulic and pneumatic – comparison, ISO symbols for fluid power elements, selection criteria	4
	Fluid power generating elements – hydraulic pumps and motorgears, vane, piston pumps-motors- selection and specification	5
II	Drive characteristics- linear actuator–types, mounting details, cushioning–power packs–accumulators	9
III	Control and regulation elements—direction, flow and pressure control valves- methods of actuation, types, sizing of ports, spool valves-operating characteristics, Electro hydraulic servo valves-different types-characteristics and performance	10
IV	Typical design methods –Ladder diagram- sequencing circuits design - combinational logic circuit design-cascade method – Karnaugh map method.	9
V	Electrical control of pneumatic and hydraulic circuits- use of relays, timers, counters ,interfacing with PLCs, proportional control of hydraulic systems	8

CODE MET398	ADVANCED NUMERICAL CONTROLLED MACHINING	CATEGORY	L	T	P	CREDIT
		VAC	3	1		4

Preamble:

This course will help the student to understand the concept of numerical control and the peripheral requirements of the NC system. It familiarise the different approaches of machining using numerical control and also to make the student familiar to the different programming methods of NC machines.

Prerequisite: Nil

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

CO 1	To study the structure of numerical control and its applications
CO 2	To understand the features and control of CNC
CO 3	To write numerical part program of simple machining
CO 4	To familiarize the structure of computer assisted part programming features
CO 5	To study the constructional and automated features of numerical controlled machining

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	2										2	2
CO 2	2				3							2
CO 3	3	2	2								2	1
CO 4	3				2							2
CO 5	3		2		3						1	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Describe the structure of NC system

2. Enumerate difference between ordinary and NC Machine tools.

3. What is Machining Capabilities of a CNC Machine,.

Course Outcome 2 (CO2)

1. Differentiate open and closed loop control system

2. Enlist features of CNC and DNC system

3 Define the adaptive control system

Course Outcome 3(CO3):

1 Define the structure of CNC part programme

2. What is Programming using tool nose radius compensation ,Tools offsets

3. Enlist the procedure of manual Programming for simple parts

Course Outcome 4 (CO4):

1. Enumerate the structure of computer assisted part programming .

2. Generation of NC Programmes through CAD/CAM systems,.

3. Post processor design and implementation

Course Outcome 5 (CO5):

1. Machine structure of CNC machines

2. Constructional features of CNC turning center and CNC machining center

3. Design consideration of CNC machines

MODEL QUESTION PAPER
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION
Course Code : MET398
Course Name : ADVANCED NUMERICAL CONTROLLED MACHINING

Max. Marks : 100 Duration : 3 Hours

PART – A
(*ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS*)

1 How does the structure of NC/CNC machine tools differ from conventional machine tools.
2 Explain clearly the difference between NC and CNC machine
3 Differentiate open loop and closed loop system in CNC machine.
4 Enumerate advantages and disadvantages of Direct numerical control
5 What is GO2 and GO3 in circular interpolation.
6 What is tool nose radius compensation and how to use it.
7 What is CAPP and discuss the benefits of CAPP
8 Discuss the code is used for canned cycle definition
9 Explain briefly swarf removal process in CNC machine.
10 What are the types of tools holders in CNC machine

PART – B
(*ANSWER ONE FULL QUESTION FROM EACH MODULE*)

Module- 1

11 a) With schematic diagram explain the basic principal of numerical. (8 Marks)
b) Explain the historical development of numerical controlled machining (6 Marks)
12 a) Explain the machining capabilities of a CNC machine tool (7 Marks)
b) Enlist and describe the advantages and dis advantages of CNC Machine (7 Marks)

Module-2

13 a) Describe the basic system of CNC machine tool (7Marks)

b) Explain programming features of CNC system (7Marks)

14 a) What is adaptive control system in CNC machining and what is its benefits (7Marks)

b) Describe the standard controllers of CNC machines (7Marks)

Module-3

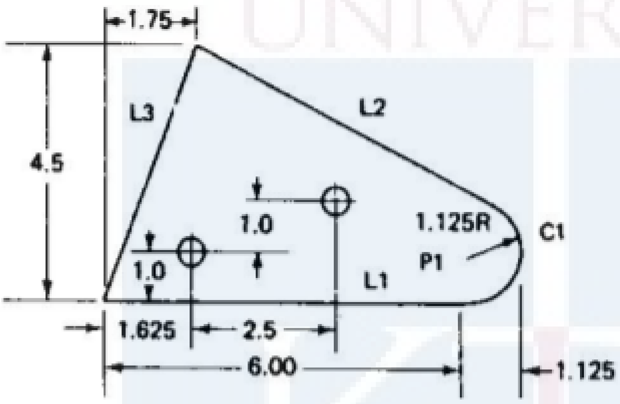
15 a) Explain the structure of NC part program (7Marks)

b) Describe the various programing functions of NC machining (7Marks)

16 a) Explain the fundamental element for developing manual part programme. (7Marks)
b) Describe various G code and M codes of NC programming. (7Marks)

Module-4

17 Write the APT program of a given basic geometry element (14Marks)



18 a) Explain the features CNC post processor. (8Marks)

b) Explain the generation of NC program through CAD/CAM system (6Marks)

Module-5

19 a) Explain Automatic tool changers and multiple pallet systems in CNC system(7Marks)

b) Describe the constructional details of CNC turning centre (7Marks)

20 a) Explain various tooling requirement of CNC system (6Marks)

b) What is CNC tool holder and what are the different types (8Marks)

Syllabus

Module 1

Principles of Numerical Control Structure of NC systems, Applications of CNC machines in manufacturing, Advantages of CNC machines. Historical developments and future trends. Future of NC Machines, Difference between ordinary and NC Machine tools, Machining Capabilities of a CNC Machine, Methods for improving accuracy and productivity.

Module 2

Control of NC Systems: Classification of CNC control systems Open and Closed loop systems, Types of CNC Machine Tools systems devices, e.g. encoders and interpolators, Features of CNC Systems, Direct Numerical Control (DNC), Standard Controllers and General Programming features available in CNC Systems, Computer Process monitoring and Control. Adaptive control systems.

Module 3

NC Part Programming: Axis identification and coordinate systems ,Structure of CNC part program, Programming codes, Programming for 2 and 3 axis control systems ,Manual part programming for a turning center ,Programming using tool nose radius compensation ,Tools offsets ,Do loops, sub routines and fixed cycles. Manual Programming for simple parts.

Module 4

Computer aided part programming; Tools for computer aided part programming, Computer aided NC Programming in APT language, use of canned cycles, Generation of NC Programmes through CAD/CAM systems, Design and implementation of post processors.

Module 5

Constructional Details of CNC Machines: Machine structure ,Slide –ways ,Motion transmission elements ,Swarf removal and safety considerations ,Automatic tool changers and multiple pallet systems, Sensors and feedback devices in CNC machines ,Constructional detail of CNC turning center and CNC machining center. **Tooling of CNC Machines** Tooling requirements of CNC machines, Pre-set and qualified tools, Work and tool holding devices in CNC machines. Design considerations of CNC machines.

Text Books

1. Radhakrishnan, P., “Computer Numerical Control Machines”, New Central Book Agencies
2. Mikell P. Groover., “ Automation, Production Systems and Computer Integrated Manufacturing”, Prentice Hall.

Reference Books

1 YoramKoren, "Computer Control of Manufacturing Systems", Tata McGraw Hill Book Co.,2005.

2 HMT, Mechatronics, Tata McGraw-Hill Publishing Company Limited, New Delhi,1998.

.

Course Contents and Lecture Schedule

No	Topic	No. of lectures
1	**Module-1- Principles of Numerical Control**	**8 Hours**
1.1	Structure of NC systems, Applications of CNC machines in manufacturing,	**2** Hr
1.2	Advantages of CNC machines. Historical developments and future trends.	1 Hr
1.3	Future of NC Machines,	1 Hr
1.4	Difference between ordinary and NC Machine tools,	1 Hr
1.5	Capabilities of a CNC Machine	1 Hr
1.6	Methods for improving accuracy and productivity	2 Hr
2	**Module 2-Control of NC Systems:**	**8 Hours**
2.1	Classification of CNC control systems	1 Hr
2.2	Open and Closed loop systems,	1 Hr
2.3	Types of CNC Machine Tools systems devices, e.g. encoders and interpolators	1 Hr
2.4	Features of CNC Systems,	1 Hr
2.5	Direct Numerical Control (DNC),	1 Hr
2.5	Standard Controllers and General Programming features available in CNC Systems,	2 Hr
2.6	Computer Process monitoring and Control. Adaptive control systems.	1 Hr
3	**Module-3- NC Part Programming**	**9 Hours**
3.1	Axis identification and coordinate systems	1 Hr

3.2	Structure of CNC part program, Programming codes	2 Hr
3.3	Programming for 2 and 3 axis control systems	1 Hr
3.4	Manual part programming for a turning center	1 Hr
3.5	,Programming using tool nose radius compensation	1 Hr
3.6	Tools offsets ,Do loops, sub routines and fixed cycles	1 Hr
3.7	Manual Programming for simple parts	2 hr
4	Module-4- **Computer aided part programming**;	**8 Hours**
4.1	Tools for computer aided part programming	2 Hr
4.2	Computer aided NC Programming in APT language	2 Hr
4.3	use of canned cycles,	1 Hr
4.4	Generation of NC Programmes through CAD/CAM systems	2 Hr
4.5	, Design and implementation of post processors.	1 Hr
5	**Module-5- Constructional Details of CNC Machines: Tooling of CNC Machines**	**12 Hours**
5.1	Machine structure ,Slide –ways ,Motion transmission elements	2 Hr
5.2	Swarf removal and safety considerations	1 Hr
5.3	Automatic tool changers and multiple pallet systems	1 Hr
5.4	Sensors and feedback devices in CNC machines	1 Hr
5.5	Constructional detail of CNC turning center	2 Hr
5.6	CNC machining center and Tooling requirements of CNC machines	1 Hr
5.8	Pre-set and qualified tools and Work and tool holding devices in CNC machines	2 Hr
5.10	Design considerations of CNC machines.	2 Hr

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET495	ADVANCED THEORY OF VIBRATIONS	VAC	4	0	0	4

Preamble:

- To understand the principles of vibration theory.
- To introduce techniques for solving vibration problems.
- To enable development of mathematical model for engineering problems in vibrations.

Prerequisite: MET 304 Dynamics and Design of Machinery

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

CO 1	Analyse the single degree of freedom vibration system with and without damping
CO 2	Analyse forced harmonic vibration and two degree of freedom system
CO 3	Analyse the multi degree of freedom system and the Eigen value problem
CO 4	Solve vibration of continuous systems and transient vibrations
CO 5	Solve the numerical methods used in vibration analysis

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3	3									
CO 2	3	3	3									
CO 3	3	3	3									
CO 4	3	3	3									
CO 5	3	3	3									

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand	10	10	30
Apply	40	40	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain about different types of vibrating mechanisms.
2. Describe Energy method and Rayleigh method.
3. Explain the different damping mechanisms.

Course Outcome 2 (CO2)

1. Describe about the magnification factor and transmissibility.
2. What is normal mode vibration and coordinate coupling.
3. Explain the working of seismometer and accelerometer.

Course Outcome 3(CO3):

1. Describe about Dynamic vibration absorbers and Vibration dampers
2. Explain the mode shape and Modal analysis.
3. What is Eigen value and Eigen vector.

Course Outcome 4 (CO4):

1. Discuss about the vibrating strings and longitudinal vibration of rods.

2. Explain the Torsional vibration of rods

3. Explain the Transient vibrations

Course Outcome 5 (CO5):

1. Explain Matrix Iteration and Stodola method– Dunkerley's method

2. Differentiate between Rayleigh method and Rayleigh –Ritz method

3. What is Holzer procedure for vibration analysis

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SEVENTH SEMESTER B. TECH DEGREE EXAMINATION
Course Code: MET 475
Course Name: ADVANCED THEORY OF VIBRATIONS

Max. Marks: 100 **Duration: 3 Hours**

PART – A

(ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS)

1. Distinguish between longitudinal, transverse and torsional vibrations?
2. What are beats?
3. Explain the working of a vibrometer?
4. How does the forcetransmitted to the base change as the speed of the machine increases?
5. What is orthogonality of modes?
6. What are influence coefficients?
7. What is the Duhamel Integral? What is its use?
8. State the boundary conditions at the end of a string.
9. What is the basic principle used in Holzer's method?
10. Write short notes on n Rayleigh Ritz Method.

PART – B

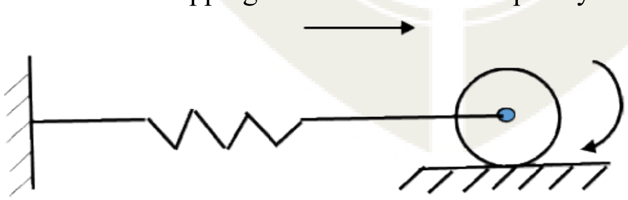
(ANSWER ONE FULL QUESTION FROM EACH MODULE)

MODULE – 1

11. A machine of mass 18kg is supported on springs of total stiffness 12N/mm and dashpot of 0.2Ns/m damping. The system is initially at rest and a velocity of 120mm/s is imparted to the machine. Determine the displacement and velocity of machine as a function of time?

(14 marks)

12. A circular cylinder as shown below, has a mass 6kg and radius 20cm, which is joined to the fixture by a spring having stiffness 5000N/m. It is free to roll on the horizontal surface without slipping. Find the natural frequency of the system?



(14 marks)

Module 2

13. A machine component having a mass of 3kg vibrates in a viscous medium. If a harmonic force 40N is applied on the on the system causes a resonant amplitude of 15mm with a period of 0.25second, find the damping coefficient? Find the increase in the amplitude of the forced when the damper is removed, if the frequency of exciting force is changed to 4 Hz?

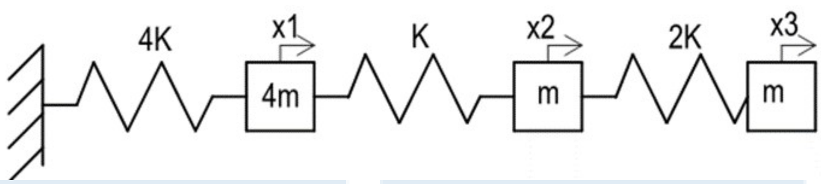
(14 marks)

14. Design Derive the general equation for damped free vibration of a single degree of freedom system? Arrive at the equation of under damped system?

(14 marks)

Module 3

15. Find out the natural frequency of the system given below usinginfluence coefficient method?



(14 marks)

16. A reciprocating machine has a weight of 250N which runs at a constant speed of 500rpm. It was found after final installation that the forcing frequency is very close to the natural frequency of the system. Find the mass of the dynamic absorber to be added to the system, the nearest natural frequency of the system should be at least 25 percent from the impressed frequency? (14 marks)

Module 4

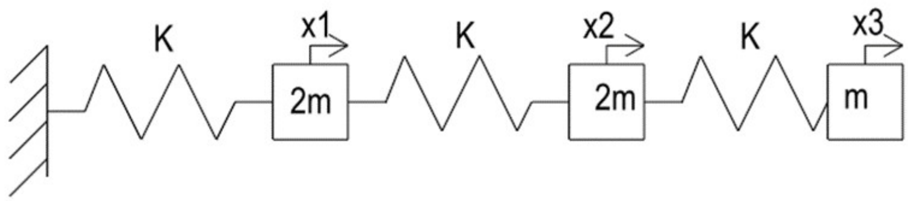
17. Derive an expression for the torsional vibration in case of a shaft having torque T acting at both the ends? (14 marks)

18. a) Derive the impulse response function of a damped free vibration system? (7 marks)
b) A trailer being pulled at a high speed, hits a h cm high curb. Considering the trailer to be single degree of freedom system, analyse the system for the response.

(7 marks)

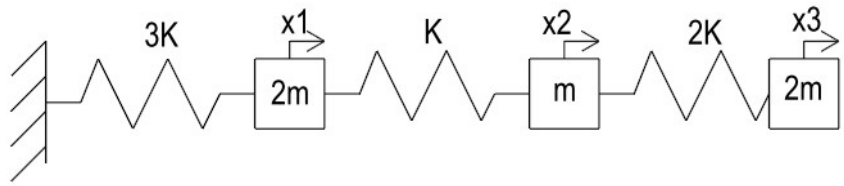
Module 5

19. Using Stodola technique determine the first natural frequency of the following system?



(14 marks)

20. Find out the natural frequency of the system given below using matrix iteration method?



(14 marks)

Syllabus

Module 1

Introduction to mechanical vibrations- Definitions -Types of vibrations- Degrees of freedom-Oscillatory motion – Periodic motion- Beat phenomenon

Free vibration of single degree of freedom systems with damping - Natural frequency using Energy method- Rayleigh method- Newton's method

Free vibration of single degree of freedom systems with damping- Viscous damping-Logarithmic decrement-

Coulomb damping- - Structural damping

Module 2

Forced harmonic vibration- Magnification Factor-Transmissibility-Vibration Isolation-Base Excitation-Rotating unbalance- whirling of shafts- Resonance

Vibration measuring instruments- Seismometer-Accelerometer

Two degree of freedom systems- Generalized co-ordinates- Normal mode vibration-Principal co-ordinates-Coordinate coupling.

Module 3

Dynamic vibration absorbers- Vibration dampers- Numerical problems

Multi degree of freedom systems- Matrix formulation- Influence Coefficients-Flexibility Matrix-Stiffness matrix

Eigen Value problem: Eigen value and Eigen Vectors-Natural Frequency- mode shape - Orthogonality of normal modes-Modal analysis

Module 4

Vibration of continuous systems-Vibrating strings- Longitudinal vibration of rods—Torsional vibration of rods

Transient vibrations- Impulse excitation- Convolution integral,Response to Arbitrary Loading.

Module 5

Numerical methods - Matrix Iteration – Stodola – Dunkerley's method - Rayleigh method – Rayleigh –Ritz method -Holzer procedure

Text Books

1. A. G. Ambekar, "Mechanical Vibrations and Noise Engineering, PHI, New Delhi

2. V.P. Singh "Mechanical Vibrations" DhanpatRai& Co (Pvt) Ltd.

Reference Books

1. Thomson W.T , Theory of Vibration with Applications., PHI, New Delhi

2. Rao V and J Srinivas, Mechanical Vibrations, PHI, New Delhi

3. S.S Rao, Mechanical Vibrations, Pearson Education India

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Introduction to mechanical vibrations- Definitions -Types of vibrations- Degrees of freedom- Oscillatory motion – Periodic motion- Beat phenomenon	3
1.2	Free vibration of single degree of freedom (DOF) systems with damping - Natural frequency using Energy method- Rayleigh method- Newton's method	3
1.3	Free vibration of single degree of freedom (DOF) systems with damping- Viscous damping- Logarithmic decrement- Coulomb damping- - Structural damping	3
2	**Module 2**	
2.1	Forced harmonic vibration- Magnification Factor- Transmissibility-Vibration Isolation-Base Excitation-Rotating unbalance- whirling of shafts- Resonance	4
2.2	Vibration measuring instruments- Seismometer-Accelerometer	2
2.3	Two degree of freedom systems- Generalized co-ordinates- Normal mode vibration-Principal co-ordinates-Coordinate coupling.	4
3	**Module 3**	
3.1	Dynamic vibration absorbers- Vibration dampers- Numerical problems	2
3.2	Multi degree of freedom systems- Matrix formulation- Influence Coefficients-Flexibility Matrix-Stiffness matrix	4
3.3	Eigen Value problem: Eigen value and Eigen Vectors-Natural Frequency- mode shape -Modal analysis	4
4	**Module 4**	
4.1	Vibration of continuous systems-Vibrating strings- Longitudinal vibration of rods—Torsional vibration of rods	4
4.2	Transient vibrations- Impulse excitation- Convolution integral.	4
5	**Module 5**	
5.1	Numerical methods - Matrix Iteration – Stodola – Dunkerley's method -	4
5.2	Rayleigh method – Rayleigh –Ritz method -Holzer procedure	4

MED496	MINI PROJECT	CATEGORY	L	T	P	CREDIT
		PWS	0	0	3	4

Preamble: Mini Project Phase I: A Project topic must be selected either from research literature or the students themselves may propose suitable topics in consultation with their guides. The object of Project Work I is to enable the student to take up investigative study in the broad field of Chemical Engineering, either fully theoretical/practical or involving both theoretical and practical work to be assigned by the Department on a group of three/four students, under the guidance of a Supervisor. This is expected to provide a good initiation for the student(s) in R&D work. The assignment to normally include:

- Survey and study of published literature on the assigned topic;
- Preparing an Action Plan for conducting the investigation, including team work;
- Working out a preliminary Approach to the Problem relating to the assigned topic;
- Block level design documentation
- Conducting preliminary Analysis/ Modelling/ Simulation/ Experiment/ Design/ Feasibility;
- Preparing a Written Report on the Study conducted for presentation to the Department;

CO1	Identify and synthesize problems and propose solutions to them.
CO2	Prepare work plan and liaison with the team in completing as per schedule.
CO3	Validate the above solutions by theoretical calculations and through experimental
CO4	Write technical reports and develop proper communication skills.
CO5	Present the data and defend ideas.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3					3	3		2
CO2	3			3				3	3	3	3	
CO3	3	3	3	3	3					3		
CO4					3			3	3	3		1
CO5	3	3	3	3				3		3	3	1

*1-slight/low mapping, 2- moderate/medium mapping, 3-substantial/high mapping

Continuous Internal Evaluation Pattern:

Sl. No.	Level of Evaluation	Marks
1	Interim evaluation by the committee	**20**
2	Project Guide	**30**
3	Final Seminar evaluation by the committee	**30**
4	The report evaluated by the evaluation committee	**20**
	Total	**100**
	Minimum required to pass	**50**

The evaluation committee comprises a panel of HoD or a senior faculty member, Project coordinator and project supervisor.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET497	COMPUTATIONAL METHODS IN FLUID FLOW AND HEAT TRANSFER	VAC	3	1	0	4

Preamble: COMPUTATIONAL METHODS IN FLUID FLOW & HEAT TRANSFER focuses on basic concept and principles of numerically solving governing equations for fluid flow and heat transfer problems.

Prerequisite: MET203 Mechanics of Fluids, MET302 Heat and Mass Transfer

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

CO 1	Explain physical and mathematical classifications partial differential equations, discretization, Steady one-dimensional conduction in Cartesian and cylindrical coordinates,,
CO 2	Analyse One-, two, and three-dimensional steady state and transient heat conduction problems in Cartesian and cylindrical coordinates
CO 3	Explain Explicit, implicit, Crank-Nicholson and ADIschemes,; consistency, stability and convergence.
CO 4	Analyse finite volume method for diffusion and convection

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	✓	✓	✓									
CO 2	✓	✓	✓									
CO 3	✓	✓	✓									
CO 4	✓	✓	✓									

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	20
Understand	20	20	40
Apply	10	10	20
Analyse	10	10	20
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the concept of discretization.

2. Explain the term " Rate of Convergence".

Course Outcome 2 (CO2)

1. Differentiate between Dirichlet and Newmann Boundary conditions.

2. Explain how discretization of irregular boundaries are done ?

Course Outcome 3(CO3):

1. Explain the significance of ADI scheme

2. Give the stability criterion of Crank Nicholson Scheme.

Course Outcome 4 (CO4):

1. Explain the reason for using finite volume method for convection and diffusion problems?

2. Differentiate between Hybrid and Upwind Schemes.

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION

Course Code: MET497

Course Name: COMPUTATIONAL METHODS IN FLUID FLOW & HEAT TRANSFER

Max. Marks: 100 Duration: 3 Hours

PART – A

(ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS)

1. What are the various errors encountered in the solution by computational methods?

2. Describe the Tridiagonal matrix algorithm (TDMA)

3. Explain the significance of line by line method of solutions

4. Give two examples of Dirichlet boundary conditions

5.Distinguish between Explicit and Implicit schemes, compare the advantages and disadvantages for each.

6. Write Crank-Nicolson FDE for $\frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2}$

7. Write a typical convection and diffusion equation in conservative form.

8. What is the benefit of conservative form of equations?

9. Differentiate between SIMPLE and SIMPLER algorthms

10. Write short notes on QUICK scheme

PART – B

(ANSWER ONE FULL QUESTION FROM EACH MODULE)

MODULE – 1

11. a) What is under relaxation? Give one formula each for PSOR and LSOR. (7 Marks)

b) Why stability is to be ensured for numerical schemes? How is it done? (7 marks)

OR

12. With the help of suitable examples explain Taylor's series approach and polynomial fitting approach (14 marks)

MODULE – 2

13. a) Explain formation of discritized equations for regular and irregular boundaries with suitable examples (14 marks)

OR

14. Explain solution procedure for two dimensional steady state heat conduction problems (14 marks)

MODULE – 3

15. a) Write and explain the ADI formulation for the PDE $\frac{\partial u}{dt} = ¿ \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}$ (9 marks)

b)Write Crank-Nicolson FDE for $\frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2}$ (5 marks)

OR

16. a) Write the ADI formulation for the PDE $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$ (6 marks)

b) Explain the stability criterion of ADI and Crank Nicolson Schemes. (8 marks)

MODULE – 4

17. Discuss advantages and limitations of the following with respect to convection and diffusion equation

i) Upwind scheme
ii) Hybrid scheme
iii) Power-Law scheme (14 Marks)

OR

18. a) Write a typical convection and diffusion equation in conservative form. (7 marks)

b) Explain the concept of false diffusion (7 marks)

MODULE – 5

19. a) What is the main difficulty in solving momentum equations (4 marks)

b) How the pressure correction equation is formulated for SIMPLE procedure (10 Marks)

OR

20. a) Explain the sequence of operations in the SIMPLE procedure with a flowchart (7 marks)

b) Explain the significance of SIMPLEC scheme using example (7 marks)

Syllabus

Module 1

Experimental, theoretical and numerical methods of predictions, physical and mathematical classifications partial differential equations; computational economy; numerical stability; validationof numerical results; round-off-error and accuracy of numerical results; iterative convergence, condition for convergence, rate of convergence; under and over relaxations, termination of iteration; tridiagonal matrix algorithm; discretization, converting derivativesto their finite difference forms, Taylor's series approach,polynomial fitting approach; discretization error.

Module 2

Steady one-dimensional conduction in Cartesian and cylindrical coordinates; handling of boundary conditions; two dimensional steady state conduction problems in Cartesian and cylindrical coordinates, point-by-point and line-by-line method of solution, dealing with Dirichlet, Neumann, and bins type boundary conditions, formation of discritized equations for regular and irregular boundaries and interfaces.

Module 3

One-, two, and three-dimensional transient heat conduction problems in Cartesian and cylindrical coordinates , explicit, implicit, Crank Nicholson and ADI schemes..Stability criterion of these schemes, conservation form and conservative property of partial differential and finite difference equations

Module 4

Finite volume method for diffusion and convection–diffusion problems, steady one dimensional convection and diffusion; upwind, hybrid and power-law schemes, discretization of equation for two dimension, false diffusion,

Module 5

SIMPLE, SIMPLER, SIMPLEC and QUICK schemes, solution algorithms for pressure velocity coupling in steady flows; numerical marching techniques, two dimensional parabolic flows with heat transfer.

Text Books

1. Anderson, D. A, Tannehill, J. C., and R. H. Pletcher, R. H., Computational Fluid Mechanics and Heat Transfer, Second Edition, Taylor & Francis,1995.

Reference Books

1. T.J. Chung, Computational Fluid dynamics, Cambridge University Press, South Asian Edition, 2003.

2. Muraleedhar, K. and T. Sundararaja, T., Computational Fluid Flow and Heat Transfer, Second Edition, Narosa Publishing House, 2003.

3. Patankar, S. V., Numerical Heat Transfer and Fluid Flow, Hemisphere, 1980.

4. Versteeg, H. K. and W. Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Addison Wesley–Longman,1995.

5. Hornbeck, R. W., Numerical Marching Techniques for Fluid Flows with Heat Transfer, NASA,

SP – 297, 1973.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1.1	Experimental, theoretical and numerical methods of predictions, physical and mathematical classifications partial differential equations; computational economy;	4
1.2	Validationof numerical results; round-off-error and accuracy of numerical results; iterative convergence, condition for convergence, rate of convergence; under and over relaxations,	3
1.3	Termination of iteration; tridiagonal matrix algorithm; discretization, converting derivativesto their finite difference forms, Taylor's series approach,polynomial fitting approach; discretization error.	3
2.1	Steady one-dimensional conduction in Cartesian and cylindrical coordinates; handling of boundary conditions; two dimensional steady state conduction problems in Cartesian and cylindrical coordinates,	3
2.2	Point-by-point and line-by-line method of solution, dealing with Dirichlet, Neumann, and bins type boundary conditions	2
2.3	Formation of discritized equations for regular and irregular boundaries and interfaces.	2
3.1	One-, two, and three-dimensional transient heat conduction problems in Cartesian and cylindrical coordinates , explicit,implicit, Crank Nicholson and ADI schemes	4

3.2	Stability criterion of these schemes, conservation form and conservative property of partial differential and finite difference equations	3
4.1	Finite volume method for diffusion and convection–diffusion problems, steady one dimensional convection and diffusion;	3
4.2	Upwind, hybrid and power-law schemes, discretization of equation for two dimension, false diffusion,	3
5.1	SIMPLE, SIMPLER, SIMPLEC and QUICK schemes, solution algorithms for pressure velocity coupling in steady flows;	3
5.2	Numerical marching techniques, two dimensional parabolic flows with heat transfer.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET499	PRECISION MACHINING	VAC	3	1	0	4

Preamble: This course is conceived to help students understand design and process issues associated with precision machining. The course introduces a few precision machining processes as well.

Prerequisite: Nil

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

CO 1	Contrast basic premises of normal machining and precision machining
CO 2	Relate consideration of error and sources of error and role of kinematic design in establishing precision.
CO 3	Explain various sensors and AE based monitoring in precision machining environment
CO 4	Outline the basics of process planning for precision machining
CO 5	Explain various precision machining processes.

Mapping of course outcomes with program outcomes:

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	1	-	-	3	-	1	-	2	1	1	1
CO 2	3	1	-	-	3	-	1	-	2	1	1	1
CO 3	3	1	-	-	3	-	1	-	2	1	1	1
CO 4	3	1	-	-	3	-	1	-	2	1	1	1
CO 5	3	1	-	-	3	-	1	-	2	1	1	1
CO 6	3	1	-	-	3	-	1	-	2	1	1	1

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination (marks)**
	1 (marks)	**2 (marks)**	
Remember	20	20	40
Understand	20	20	40
Apply	10	10	20
Analyse	-	-	-
Evaluate	-	-	-
Create	-	-	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module, of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What is Abbe's principle? List an instrument each which (a) obeys Abbe's principle (b) disobeys Abbe's principle.
2. List down various methods for testing roundness. Explain precision spindle method for checking roundness with a suitable diagram.
3. With the help of a neat diagram, explain surface roughness terminology.

Course Outcome 2 (CO2):

1. With the help of a suitable diagram, show the directions in which errors occur for a conventional machine tool.
2. What is an error budget? How does an error budget flow chart help in generating it?
3. Describe thermal effects in precision machining.

Course Outcome 3 (CO3):

1. Explain AE based topographical mapping of grinding wheels.
2. Describe AE based monitoring of face milling.
3. Explain fast AE RMS analysis for wheel condition monitoring.

Course Outcome 4 (CO4):

1. Define capability ratio.
2. Discuss the basics of process planning in precision machining process?
3. Illustrate with an example the application of capability ratio in process planning.

Course Outcome 5 (CO5):

1. Discuss typical fly cutting diamond machine configurations.
2. Discuss tool-workpiece configurations for conical- circumferential milling.
3. Discuss the tool geometry of a typical single point diamond tool.

Model Question Paper

MET499 PRECISION MACHINING

Max. Marks: 100 Duration: 3 hours

Part−A

Answer all questions. Each question carries 3 marks

.

1. Enumerate critical elements in precision manufacturing.
2. Clearly distinguish the terms accuracy, precision and resolution.
3. Distinguish between kinematic design and elastically averaged design.
4. What do you understand by macroscale and microscale structural compliance?
5. Which are the basic sensor types used in precision manufacturing set ups?
6. Tabulate various forms of energy converted by sensors.
7. Define process capability.
8. What are the factors that affect precision during machining?
9. Differentiate between fixed abrasive process and loose abrasive process.
10. Draw a schematic and hence outline a nano-grinding process.

Part−B

Answer one full question from each module.

Module I

11. Differentiate normal machining, precision machining and ultra-precision machining with examples (14 marks)

OR

12. Describe various "competitive drivers" of precision manufacturing. (14 marks)

Module II

13. What do you understand by microscale and macroscale structural compliance. Explain. (14 marks)

OR

14. With the help of a neat diagram explain Air bearing grinding spindle. (14 marks)

Module III

15. Explain requirements for sensor technology for precision machining. (14 marks)

OR

16. Describe an optical system for monitoring of grinding wheel topography. (14 marks)

Module IV

17. Describe how process capability can be used as a planning metric for transition from one process stage to another. (14 marks)

OR

18. Discuss four levels of integration between the tasks of design, manufacturing and finishing. (14 marks)

Module V

19. With the help of a diagram explain CMP process. (14 marks)

OR

20. Explain the process of diamond turning with suitable diagrams. (14 marks)

Syllabus

Module 1

Introduction to precision machining: Competitive drivers for precision machining. Definition of terms- accuracy, precision and resolution. Metrology and measurement- Abbe's principle. Measurement of dimension and angle- measurement of form- straightness, flatness and roundness. Measurement of surface roughness.

Module 2

Sources of error in precision machining: Mechanical errors- errors due to machine elements, thermal errors, Error due to compliance and vibration. Error budget- error budget flow chart- (elementary idea only). Role of kinematic design in precision. Principles of design and utilisation of bearings-aerostatic bearings.

Module 3

Sensors in precision machining: Classification of basic sensor types- overview of sensors in manufacturing- applications- AE based monitoring of grinding wheel dressing- fast AE RMS analysis of wheel condition monitoring (description only). Topographical mapping of grinding wheel. AE based monitoring of face milling.

Module 4

Process planning for precision machining: process planning basics-factors which influence precision-process capability-relationship between process variability and product specification- process capability as a planning metric.

Module 5

Precision machining processes: Diamond turning and milling, fly cutting diamond machine configuration- features of diamond machine tool design- applications. Configuration for conical circumferential milling- applications. Typical single point diamond tool geometry. Abrasive processes-fixed and loose. Nano grinding-Chemical mechanical Planarization (CMP)- precision manufacturing applications.

Text Books and References

1. David Dornfeld, Dae-Eun Lee, Precision Manfacturing, Springer, 2008
2. V.C. Venkatesh, Sudin Izman, Precision Engineering, Tata McGraw- Hill, 2007
3. Michael N. Morgan, Andrew Shaw, Otar Mgaloblishvili, Precision Machining VI, Transtech publications Ltd, Switzerland, 2012

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1.1	Introduction to precision machining.	1
1.2	Philosophy of precision machine design	1
1.3	Competitive drivers for precision machining	2
1.4	Definition of terms- accuracy, precision and resolution	1
1.5	Metrology and measurement – Abbe's principle	1
1.6	Measurement of dimension and angle	1
1.7	Measurement of form- straightness, flatness and roundness	1
1.8	Measurement of surface roughness	1
2.1	Sources of error in precision machining	2
2.2	Mechanical errors – errors due to machine elements, thermal errors	2
2.3	Errors due to compliance and vibration	1
2.4	Error budget	1
2.5	Error budget flow chart	1
2.6	Role of kinematic design in precision	1
2.7	Principles of design and utilisation of bearings – Aerostatic bearings	1
3.1	Sensors in Precision Machining- classification	2
3.2	Overview of sensors and applications	1
3.3	AE based monitoring of grinding wheel dressing	1
3.4	Description of Fast AE RMS analysis of wheel condition monitoring	1
3.5	Topographical mapping of grinding wheel	1

3.6	AE based monitoring of face milling	1
4.1	Process planning for precision machining	2
4.2	Process planning basics	1
4.3	Factors influencing precision.	1
4.4	Process capability	2
4.5	Relationship between process variability and product specification	1
4.6	Process capability as a planning metric	1
5.1	Precision machining Processes – Diamond turning and milling	1
5.2	Fly cutting diamond machine configuration	1
5.3	Features of diamond machine tool design-applications	1
5.4	Configuration for conical circumferential milling- applications	1
5.5	Typical single point diamond tool geometry	1
5.6	Abrasive processes- fixed and loose	1
5.7	Nano grinding	1
5.8	Chemical Mechanical Planarization	1
5.9	Precision manufacturing applications	1