SEMESTER I

Discipline: Electrical & Electronics Engineering

Stream: Industrial Instrumentation and Control, Instrumentation and Control, Control Systems

Course No.	Course Name	L-T-P-Credits	Year of Introduction
221TEE100	LINEAR ALGEBRA AND LINEAR SYSTEMS	3 - 0 - 0	2022

Preamble: Nil

Course Prerequisites

Basic knowledge of engineering mathematics at UG level.

Course Objectives

To equip the student with mathematical techniques necessary for computing applications in engineering systems

Course Outcomes:

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

CO 1	Explain the concepts of vector spaces.
CO 2	Apply linear transformations in linear systems
CO 3	Solve systems of linear equations and interpret their results
CO 4	Solve LTI and LTV Systems
CO 5	Analyse linear systems.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	2	2	2	
CO 2			3	3	3	2	
CO 3			3	3	3	2	
CO 4			3	3	3	2	
CO 5			3	3	3	2	

Assessment Pattern

Bloom's Category	End Semester

EE1

	Examination
Apply	30%
Analyse	30%
Evaluate	20%
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

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

End Semester Examination Pattern:

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solvingM Tech Regulations, Curriculum 2022 and quantitative evaluation), with minimum one question from each module of which student shall answer any five . Each question can carry 7 marks. Total duration of the examination will be 150 minutes

EE1

Model Question Paper

Pages **SLOT**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

221TEE100: LINEAR ALGEBRA AND LINEAR SYSTEMS

Max. Marks: 60 **Time: 2.5 hrs**

	Part A **(Answer all questions)**	**Marks**
1	How orthogonality is defined between vectors? Check whether the vectors $v_1 = [1, 2, 1], v_2 = [1, -1, 1]$ are orthogonal or not? If $S = \{v_1, v_2, ..., v_n\}$ is the set of n mutually orthogonal vectors what is the dimension of the space spanned by the set S? Justify your answer?	(5)
2	Show that null space is the orthogonal complement of row space of a linear transformation matrix	(5)
3	Show that similarity transformation doses not change the Eigen values of a linear transformation matrix	(5)
4	What are Eigen vectors of a linear transformation? Find a non-singular matrix P such that $P^T AP$ is diagonal $A = \begin{bmatrix} 1 & 1 & 2 \\ 0 & 3 & 2 \\ 1 & 3 & 9 \end{bmatrix}$	(5)
5	Derive the expression for the controllability Grammian matrix of a linear system	(5)
	Part B	

EE1

	(Answer any five questions)	
6	With the help of a suitable example analyze the stability of a system by pole zero cancellation.	(7)
7	Define inner product space? Consider the following polynomial $P(t)$ with inner product given by $< f, g >= \int_0^1 f(t)g(t)dt$ find i) $< f, g >$ and (ii) $\parallel f \parallel, \parallel g \parallel$ if $f(t) = t + 2, \quad g(t) = 3t - 2$	(7)
8	Find the Jordan canonical form of the matrix $A = \begin{bmatrix} 2 & 0 & 1 & -3 \\ 0 & 2 & 10 & 4 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}$	(7)
9	Explain in detail the separation principle in the design of control systems.	(7)
10	What is the significance of a observability Grammian matrix. Derive the expression for the observability Grammian matrix of a linear system.	(7)
11	What is minimum polynomial of a linear transformation? Find all the Eigen values of $B = \begin{bmatrix} 3 & -1 & 1 \\ 7 & -5 & 1 \\ 6 & -6 & 2 \end{bmatrix}$ what is meant by geometric multiplicity of an Eigen value? Find geometric multiplicity of Eigen values of B?.	(7)
12	Derive the Ackermanns formula to obtain the state feedback gain matrix.	(7)

Text book:

1. Erwin Kreyszig, Advanced Engineering Mathematics 9th Edition, Wiley International Edition Press, Numerical Recipes for scientific computing,

2. Thomas Kailath, Linear Systems

References:

1. Bhaskar Dasgupta, Applied Mathematical Methods, Pearson,

2. Arfken, Weber and Harris, Mathematical Methods for Physicists, A comprehensive guide, 7th Edition, Elsevier, 2013

Syllabus

Module I

Vector Spaces - Spaces and Subspaces, Four Fundamental Subspaces, Spanning sets, Linear Independence, Basis and Dimension

Module II

Linear Transformations – Space of Linear Transformations, Matrix representation of linear transformations, Change of Basis and Similarity

Module III

Solutions to Linear System of Equations, Rectangular Systems and Echelon Forms, Homogeneous and Non homogeneous systems, Eigenvalues, Eigenvectors, Eigenspaces, Diagonalizability.

Module IV

Linear Systems - Solutions to LTI and LTV Systems, Analysis of stabilization by pole zero cancellation - Initial conditions for Analog- Computer Simulation, Controllability, Controllabilty Grammians , Stabilizability, Controllable Subspaces, controllable and uncontrollable modes.

Module V

Reachability and Constructability, Reachable Subspaces, Observability, Observability Grammians, Observable Decomposition, Kalman Decomposition, State feedback Controller Design, Observer Design, separation principle - combined observer controller configuration.

Course Plan

No	Topic	No. of Lectures
1	Vector Spaces	
1.1	Spaces and Subspaces.	1
1.2	Four Fundamental Subspaces	2

1.3	Spanning sets	1
1.4	Linear Independence	2
1.5	Basis and Dimension	2
2	Linear Transformations	
2.1	Space of Linear Transformations	2
2.2	Matrix representation of linear transformations	3
2.3	Change of Basis and Similarity	3
3	Solutions to Linear System of Equations	
3.1	Rectangular Systems and Echelon Forms	2
3.2	Homogeneous and Non homogeneous systems	2
3.3	Eigenvalues, Eigenvectors, Eigenspaces	2
3.4	Diagonalizability	2
4	Linear Systems	
4.1	Solutions to LTI and LTV Systems	2

4.2	Analysis of stabilization by pole zero cancellation - Initial conditions for Analog- Computer Simulation	2
4.3	Controllability, Controllability Grammians , Stabilizability	2
4.4	Controllable Subspaces, controllable and uncontrollable modes	2
5		
5.1	Reachability and Constructability, Reachable Subspaces	1
5.2	Observability, Observability Grammians	1
5.3	Observable Decomposition, Kalman Decomposition	2
5.4	State feedback Controller Design	2
5.5	Observer Design, separation principle - combined observer controller configuration	2

CODE 221TEE013	COURSE NAME DISCRETE TIME CONTROL SYSTEMS	CATEGORY	L	T	P	CREDIT
		PROGRAM CORE 1	3	0	0	3

Preamble: To design a suitable digital controller and observer for the system to meet the performance specifications and to evaluate its performance

Course Outcomes:

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

CO 1	Analyse a discrete-time system and evaluate its performance
CO 2	Design suitable digital controller for the system to meet the performance specifications
CO 3	Design a digital controller and observer for the system and evaluate its performance
CO 4	Analyse a MIMO discrete-time system and evaluate its performance

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	3	2		
CO 2			3	3	3		
CO 3			3	3	3		
CO 4			3	3	2		

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 40 marks

Micro project/Course based project : 20 marks
Course based task/Seminar/Quiz : 10 marks
Test paper, 1 no. : 10 marks
The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

EE1

End Semester Examination: 60 marks

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

Model Question paper

No. of Pages:3

B

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION

MONTH & YEAR

Branch: **Electrical &Electronics Engineering**

Course Code & Name: 221TEE013 **DISCRETE TIME CONTROL SYSTEMS**

Answer *all* questions from part A and any five questions from part B Limit answers to the required points.

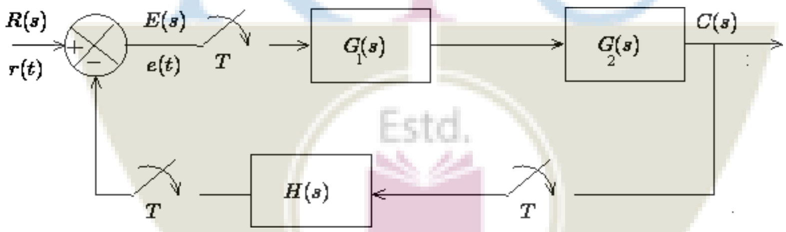
Max. Marks: 60 Duration: 2.5 hours

PART A

1. a. Explain the sampling process and loss of information and noise due to sampling — 2

   b. Obtain the z-transform of the function $f(k) = k^2 u(k),\ where, u(k) = 1,\ k \geq 0,\ k < 0$ — 3

2. Obtain the pulse transfer function of the system shown below: — 5



3. For a unity feedback system, with sampling time T=1sec, open loop pulse transfer function — 5

$$G(z) = \frac{K(0.3679z + 0.2542)}{(z - 0.3679)(z - 1)}.$$

isDetermine the value of K for stability by use of Jury'sstability test. Also determine the frequency of oscillations at the output

4. Explain controllability & observability of digital systems. — 5

5. Consider a multi output linear system described by the state model — 5

$$x(k+1) = Fx(k) + Gu(k)$$

$$y(k) = Cx(k) - Du(k)$$

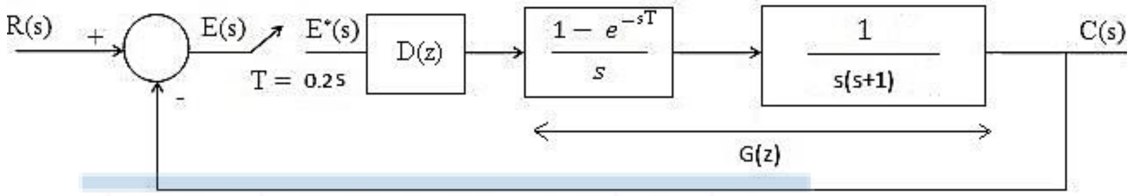
where,

$$F = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -2 & 1 & -1 \end{bmatrix}, G = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 1 & 1 \end{bmatrix}, C = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}, D = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

Check whether the system is observable

PART B

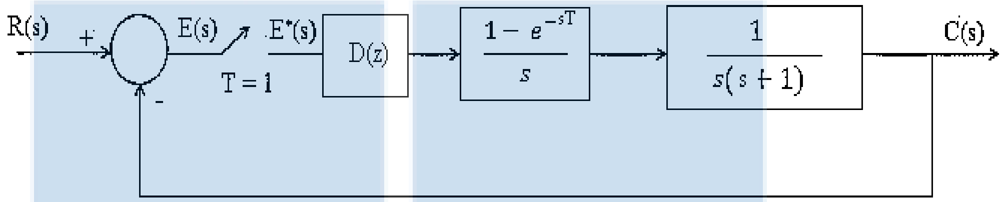
6. Consider the digital control system shown in figure. Design a digital controller D(z) such that the closed loop system has a damping ratio 0.5 and the number of samples per cycle of damped sinusoidal oscillation to be 0.8 — 7



7. For the system shown, find — 7

a. Phase margin of the system when D(z) =1

b. Design a unity dc gain phase lag compensator D (z) that yields a phase margin of approximately 45 degrees.



8. Explain the concept and procedure for designing a lag compensator using root locus method. — 7

9. For the system G(s)=1/(s (s+1)),design a lead compensator in z plane such that the compensated system will have a Phase margin of 45°.Assume the sampling period T to be 1 sec — 7

10 Consider the discrete time system defined by the equations $x(k+1) = Gx(k) + Hu(k)$, $y(k) = Cx(k)$ where — 7

$$G=\begin{bmatrix}0 & 0 & -0.25\\ 1 & 0 & 0\\ 0 & 1 & 0.5\end{bmatrix},\ H=\begin{bmatrix}1\\0\\1\end{bmatrix},\ C=\begin{bmatrix}1 & 0 & 0\end{bmatrix}$$

. Assuming that the output y(k) is measurable, design a minimum order observer, such that the error will exhibit deadbeat response

11 Prove that if a discrete system is completely state controllable and observable, then there is no pole zero cancellation in the pulse transfer function. — 7

12 Explain the algorithm for placing poles in a multivariable system. — 7

EE1

Syllabus and Course Plan

No	Topic	No. of Lectures
1.1	z-Plane Analysis of Discrete-Time Systems	
1.1.1	Review of Z Transforms	2
1.1.2	Sampling Theorem, Impulse Sampling and Data Hold, Sampling Rate Selection	1
1.1.3	Pulse Transfer Function,	2
1.1.4	Mapping between the s-plane and the z-plane	1
1.2	Stability analysis of closed-loop system in the z-plane	
1.2.1	Jury's test, Schur-Cohn test,	2
1.2.2	Bilinear Transformation, Routh-Hurwitz method in w-plane	1
2	Digital Controller Design Based on Root locus Approach	
2.1	Direct design based on root locus	2
2.2	Design of Lag Compensator	2
2.3	Design of Lead Compensator	2
2.4	Design of Lead-Lag Compensator	2
3	Digital Controller Design inFrequency Domain	
3.1	Direct design based on frequency response	2
3.2	Design of Lag Compensator	2
3.3	Design of Lead Compensator	2
3.4	Design of Lag-Lead Compensator	2
4	Design using State Space approach	
4.1	Discretization of continuous time state-space equations	1
4.2	Controllability	1
4.3	Observability	1
4.4	Design via Pole Placement	2
4.5	State Observer Design,	
4.5.1	Full order observers	2
4.5.2	Reduced order observers	2
5	Multivariable Digital Systems	
5.1	Solution of Linear Digital State Equations	2
5.2	Controllability/ Observability Indices	1
5.3	State feedback for MIMO systems	3

Reference Books

1. C. L. Philips, H. T. Nagle, Digital Control Systems, Prentice-Hall, Englewood Cliffs, New Jersey, 1995.

2. M. Gopal, Digital Control and State Variable Methods, Tata McGraw-Hill, 1997.

3. K. Ogata, Discrete-Time Control Systems, Pearson Education, Asia.

4. R. G. Jacquot, Modern Digital Control Systems, Marcel Decker, New York, 1995.

5. Benjamin C. Kuo, Digital Control Systems, 2/e, Saunders College Publishing, Philadelphia, 1992.

6. Gene F. Franklin, J. David Powell, Michael Workman, Digital Control of Dynamic Systems, Pearson, Asia.

7. J. R. Liegh, Applied Digital Control, Rinchart& Winston Inc., New Delhi.

8. Frank L. Lewis,Applied Optimal Control& Estimation, Prentice-Hall, Englewood Cliffs NJ, 1992.

221TEE014	OPTIMAL CONTROL THEORY	CATEGORY	L	T	P	CREDIT
		PROGRAM CORE 2	3	0	0	3

Preamble: This course aims to provide a foundation to formulate and solve optimal control problems using techniques such as calculus of variations, dynamic programming etc.

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

CO 1	To choose a suitable performance measure to meet the specific requirements for a system and to formulate optimal control problems.
CO 2	To solve optimal control problems using calculus of variations
CO 3	To solve optimal control problems with control and state constraints
CO 4	To solve optimal control problems using dynamic programming
CO 5	To solve optimal control problems using Hamilton-Jacobi-Bellman equations

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3		3	3			
CO 2	3		3	3	2		
CO 3	3		3	3	2		
CO 4	3		3	3			
CO 5	3		3	3	2		

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project: 20 marks

Course based task/Seminar/Quiz: 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper

shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

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

Model Question Paper

Pages **SLOT**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

221TEE014: Optimal Control Theory

Max. Marks: 60 **Time: 2.5 hrs**

	Part A **(Answer all questions)**	**Marks**
1	Check whether the functional is linear $J=\int_{t0}^{tf}(2x^2(t)+3x(t)+4)dt.$ Also find the first variation	(5)
2	Write the necessary conditions to be satisfied by an extremal Hamiltonian for a system with a standard performance measure and whose control is unconstrained.	(5)
3	Explain bang-bang control.	(5)
4	Explain the principle of imbedding.	(5)
5	Why are the LQR problems called so? Also write the performance measure for a standard LQR problem	(5)
	Part B **(Answer any five questions)**	
6	State and prove the fundamental theorem of calculus of variation	(7)
7	Determine $\dot{x}_1(t) = x_2(t) + u_1(t)$ $\dot{x}_2(t) = u_2(t)$ Find an optimal control that will extremize the performance measure $J = \int_0^1 (u_1^2(t) + u_2^2(t))dt$ such that $[x_1(0)\ x_2(0)]^T = [1\ 1]^T$ and $x_1(1) = 0$ after defining the Hamiltonian.	(7)
8	Prove that for the time optimal control in a LTI system, the necessary condition for the existence of singularity in control is that loss of controllability.	(7)

9	A first order discrete-time system is described by $x(k+1) = -0.5x(k) + u(k)$ where the performance measure to be minimized is $J = \sum_{k=0}^{2} \lvert x(k) \rvert$ and the admissible states are constrained by $-0.2 \le x(k) \le 0.2$, $k = 0,1,2$ and control are constrained by $-0.1 \le u(k) \le 0.1$, $k = 0,1$. Find the optimal control sequence from all choices of $x(0)$ values, using dynamic programming after quantizing both states and control in steps of 0.1. Use linear interpolation if necessary.	(7)
10	For the system described by $\dot{x}(t) = x(t) + u(t)$, find the control law that minimize the performance measure $$J = \frac{1}{4}(x^2(T)) + \frac{1}{4}\int_{t=0}^{T} (u^2(t))\, dt$$ when T= 2 and also find the control law when T tends to infinity using HJB equation.	(7)
11	Prove that a straight line represents a minimum distance between two fixed points x_o and x_f in the $t - x$ plane where $x_o = x(t_o)$ and $x_f = x(t_f)$, t_o is known and final t which is t_f is fixed	(7)
12	Derive the recurrence relation in dynamic programming.	(7)

Syllabus

Module 1

Optimization problems vs optimal control problems, Optimal control problem formulation- -selection of performance measures, constraints- classification- problem formulation – examples, Calculus of Variations: basic concepts - variation of a functional - extremals – fundamental theorem of calculus of variation - Euler Equation-Cases with various conditions on final state and time-fixed end point and free end point problems.

Module 2

Piecewise smooth extremals, constrained minimization of functionals – Point constraints, differential equation constraints, isoperimetric constraints, Hamiltonian -necessary conditions for optimal control, problems with different boundary conditions

Solution of optimal control problem with calculus of variations approach using MATLAB (demo/assignment only)

Module 3

Pontryagin's Minimum Principle, State variable inequality constraints, the set of reachable states, Minimum time problems-bang bang control, Minimum Fuel problems-bang off bang control - Minimum energy problems, Singular intervals- Numerical Examples.

Solution of optimal control problem with control and state constraints using MATLAB (demo/assignment only)

Module 4

Dynamic Programming - Optimal control law-principle of optimality - Application to decision making problems-routing problem-application to typical optimal control problem, Interpolation, recurrence relation in dynamic programming.

Module 5

Hamilton Jacobi Bellman equation- Standard Regulator Problem: Continuous linear regulator Problems – Discrete Linear Regulator Problems –Finite time Vs Infinite time regulator Problems – Stability of linear regulator problems.

Solution of LQR problem, solution of matrix Riccati equation- using MATLAB (demo/assignment only)

Course Plan

No	Topic	No. of Lectures
1		
1.1	Optimal control problems	1
1.2	mathematical models-selection of performance measures, constraints- classification - problem formulation – examples	2
1.3	Calculus of Variations: basic concepts - variation of a functional - extremals	1
1.4	fundamental theorem in calculus of variation - Euler equation-	2
1.5	Cases with various conditions on final state and time.	2
2		
2.1	Piecewise smooth extremals	1
2.2	constrained minimization of functionals – Point constraints,	2
2.3	differential equation constraints, isoperimetric constraints,	2
2.4	Hamiltonian -necessary conditions for optimal control, problems with different boundary conditions	2
3		
3.1	Pontryagin's Minimum Principle	1
3.2	State variable inequality constraints	1
3.3	the set of reachable states, Minimum time problems-bang bang control,	2
3.4	Minimum Fuel problems-bang off bang control-Minimum energy problems	2

3.5	Singular intervals- Numerical Examples.	2
4		
4.1	Dynamic Programming	2
4.2	Optimal control law-principle of optimality - Application to decision making problems-routing problem	3
4.3	application to typical optimal control problem	2
4.4	Interpolation,	1
4.5	recurrence relation in dynamic programming	1
5		
5.1	Hamilton Jacobi Bellman equation-	2
5.2	Standard Regulator Problem: Continuous linear regulator Problems Finite time Vs Infinite time regulator Problems	2
5.3	Discrete Linear Regulator Problems	2
5.4	Stability of linear regulator problems	2

Reference Books

1. Optimal Control, Frank L. Lewis, Draguna Vrabie, Vassilis L. Syrmos, 3rd Edition, wiley publisher -2012
2. Donald E. Kirk, Optimal Control Theory - An Introduction, Prentice-Hall Inc. Englewood Cliffs, New Jersey, 1970.
3. Brian D. O. Anderson, John B. Moore, Optimal Control-Linear Quadratic Methods, Prentice-Hall Inc., New Delhi, 1991.
4. Athans M. and P. L. Falb, Optimal control- An Introduction to the Theory and its Applications, McGraw Hill Inc., New York, 1966.
5. Sage A. P., Optimum Systems Control, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1968.
6. D. S. Naidu, Optimal Control Systems, CRC Press, New York Washington D. C., 2003.

EE1

CODE 221EEE070	Introduction to Flight	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: To give basic concepts of aerodynamics, principles, performance of airfoils, standard atmosphere and performance of flight to analyze the characteristics of the aircraft.

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

CO 1	Analyze aerodynamic performance of NACA series of airfoils as per NACA standards
CO 2	Develop aerodynamic characteristics of an airfoil at specified Mach number.
CO 3	Apply the concepts of standard atmosphere for analysing the characteristics of aircraft
CO 4	Assess standard atmosphere and the variation of pressure, temperature and density with height.
CO 5	Compare the different flow regimes based on Mach number and Compare the performance of different airfoil shapes.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	1		1	3	1	1	
CO 2	3		2	3	2	1	
CO 3	2		1	2	1	2	
CO 4	1		1	2	2	2	
CO 5	2		2	3	1	2	

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

EE1

Continuous Internal Evaluation: 40 marks

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

End Semester Examination Pattern: 60 Marks

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

Model Question paper

PART A

*(Answer **All** Questions)* (5X5 = 25 Marks)

1. The pressure and temperature at certain unknown altitude are measured to be 71800 N/m^2 and -10° C. Investigate the stability of atmosphere between mean sea level and the unknown altitude. Compute unknown altitude. Assume a linear variation of temperature with altitude.

2. An airplane is flying at a standard altitude of 5 km with a velocity of 270 m/s. At a point on the wing on the airplane, the velocity is 330 m/s. Calculate pressure at this point. Assume incompressible flow.

3. An aircraft flying at a density altitude of 3km with a speed of 100m/s. If the free stream density at the above altitude is 0.909 kg/m^3, find induced drag on the airplane. The aircraft is with a weight of 7.5×10^5 N, wing area of 206 m^2 and aspect ratio of 10.

4. A NACA 4412 airfoil is tested in a wind tunnel at standard sea-level conditions and a test section velocity of 240 ft/sec and an angle of attack of 8deg. The airfoil is with 2 ft chord and 5 ft span. Find the airfoil's maximum thickness, maximum camber, location of maximum camber, and zero-lift angle of attack? Also, calculate the lift, drag, and pitching moment about the aerodynamic center. Use airfoil data of NACA 4412.

5. Consider a Boeing 747 airliner cruising at a velocity of 550 mi/h at a standard altitude of 38,000 ft, where the freestream pressure and temperature are 432.6 lb/ft2 and 390°R, respectively. A one-fiftieth scale model of the 747 is tested in a wind tunnel where the temperature is 430°R. Calculate the required velocity and pressure of the test airstream in the wind tunnel such that the lift and drag coefficients measured for the wind-tunnel model are the same as for free flight. Assume that both μ and a are proportional to $T^{1/2}$.

PART B

*(Answer **Any Five** Questions)* (7X5 = 35 Marks)

6. Derive the expression for the variation of pressure and density in gradient layer. Also, deduce the stability conditions of the atmosphere.

7. Give the significance of velocity gradient in the boundary layer of an airfoil and deduce the relation between velocity gradient and shear stress at the airfoil wall.

8. Differentiate between aerodynamic center and center of pressure. Also give its significance with the variation of angle of attack.

9. a) Justify the influence of swept wing to delay the drag divergence in subsonic aircrafts. (4)

   b) How a super critical airfoil delays the drag divergence to a higher Mach number? (3)

10. a) Deduce the PI terms for force coefficient and Reynolds number using Buckingham PI theorem. (3)

    b) Give the significance of Mach number and compressibility in the variation of coefficient of pressure in an airfoil (4)

11. Compare the shock waves of thin and thick airfoils with neat sketches. Also deduce the relation between Mach wave and Mach angle.

12. Differentiate between primary and secondary control surfaces. Explain the functions of each control surfaces.

Syllabus

Module I

Standard atmosphere -definition of altitudes-density, pressure and temperature altitudes - Layers of atmosphere- isothermal and gradient layers- calculation of pressure, temperature and density in stratosphere and troposphere - Lapse rate –stability of atmosphere.

Module II

Aerodynamic flows - inviscid and viscous flows-incompressible and compressible flows-Mach number-subsonic, transonic, supersonic and hypersonic flow regimes- Boundary layer-laminar and turbulent flows- Reynolds number. compressibility-isentropic flow-speed of sound.

Module III

Airfoil: Airfoil nomenclature-symmetric and cambered airfoils, aspect ratio-chord line –angle of attack- Wings-wing geometry-downwash and induced drag- wash-in and wash-out- swept wings - Control surfaces-elevator-aileron-rudder-canard-tail plane-loads on tail plane-dihedral angle-dihedral effect-flaps and slots-spoilers

Module IV

Aerodynamic forces and moments- Pressure and shear stress distribution- pressure distribution over airfoil-generation of lift- Aerodynamic coefficients-lift, drag and moment coefficients-variation with angle of attack-aerodynamic centre and centre of pressure-dynamic pressure-pressure coefficient- characteristics of ideal airfoil-stalling of airfoil-lift curve, drag curve and lift/drag ratio curve- NACA airfoils-modern low speed airfoils-super critical airfoils-

Module V

Vorticity and circulation- dimensional analysis-Buckingham Pi theorem- aerodynamic heating- Critical Mach number-drag divergence Mach number-Mach angle-Mach number independence-flow similarity-drag polar. Wind tunnels-open, close and variable density wind tunnels -Classification of aerospace vehicles-aircrafts helicopters-launch vehicles-missiles-unmanned aerial vehicles and spacecraft. Basic concepts of high speed aerodynamics and aero elasticity.

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Course Plan

No	Topic	No. of Lectures
1	Standard atmosphere	
1.1	Standard atmosphere -definition of altitudes-density, pressure and temperature altitudes -	2
1.2	Layers of atmosphere- isothermal and gradient layers-calculation of pressure, temperature and density in stratosphere and troposphere	4
1.3	Lapse rate –stability of atmosphere.	2
2	Aerodynamic flows	
2.1	Aerodynamic flows - -inviscid and viscous flows-incompressible and compressible flows-	3
2.2	Mach number-subsonic, transonic, supersonic and hypersonic flow regimes-	2
2.3	Boundary layer-laminar and turbulent flows- Reynolds number. compressibility-isentropic flow-speed of sound.	3
3	Airfoil	
3.1	Airfoil nomenclature-symmetric and cambered airfoils, aspect ratio-chord line –angle of attack	3
3.2	Wings-wing geometry-downwash and induced drag-wash-in and wash-out- swept wings.	2
3.3	Control surfaces-elevator-aileron-rudder-canard-tail plane-loads on tail plane- dihedral angle-dihedral effect-flaps and slots-spoilers	3
4		
4.1	Aerodynamic forces and moments- Pressure and shear stress distribution- pressure distribution over airfoil-generation of lift-	3
4.2	Aerodynamic coefficients-lift, drag and moment coefficients-variation with angle of attack-aerodynamic centre and centre of pressure- dynamic pressure-pressure coefficient-	3
4.3	characteristics of ideal airfoil-stalling of airfoil-lift curve, drag curve and lift/drag ratio curve- NACA airfoils-modern low speed airfoils-super critical airfoils-	2
5		
5.1	Vorticity and circulation- dimensional analysis-Buckingham Pi theorem- aerodynamic heating-	4
5.2	Critical Mach number-drag divergence Mach number-Mach angle-Mach number independence-flow similarity-drag polar.	2
5.3	Wind tunnels-open, close and variable density wind tunnels -Classification of aerospace vehicles-aircrafts helicopters-launch vehicles-missiles-unmanned aerial vehicles and spacecraft. Basic concepts of high speed aerodynamics and aero elasticity.	2

EE1

Reference Books

1. John D Anderson Jr, 'Introduction to flight' McGraw Hill International, 5/e, 2005

2. John D Anderson Jr, 'Fundamentals of Aerodynamics' McGraw Hill International, 4/e, 2007

3. Richard S Shevell, 'Fundamentals of Flight' Pearson Education Inc. 2/e, 2004

4. A. C. Kermode, ''Mechanics of Flight', Pearson Education, 10/e, 2005.

5. Bernard Etkin, 'Dynamics of flight Stability and Control', John Wiley and Sons Inc. 3/e, 1996.

6. E. L. Houghton and N.B. Carruthers 'Aerodynamics for Engineering Students', Arnold Publishers, 3/e, 1986.

7. Thomas R. Yechout, 'Introduction to Aircraft Flight Mechanics', A1AA Education Series, 2003

8. Louis V. Schmidt 'Introduction to Aircraft Flight Dynamics', AIAA Education Series, 1997

CODE 221EEE030	MACHINE LEARNING	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course enables the learners to understand the fundamental concepts in machine learning. The course covers the basic introduction, various estimation methods, most popular supervised and unsupervised learning algorithms. Course also throws light to neural network systems and classifier estimation process. This course will students to create machine learning based solutions to various real-world problems.

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

CO 1	Illustrate machine learning concepts and basic parameter estimation methods along with central tendency measures. **(Cognitive Knowledge Level: Apply)**
CO 2	Describe the underlying mathematical relationships within and across Machine Learning algorithms and the paradigms of supervised learning. **(Cognitive Knowledge Level: Apply)**
CO 3	Illustrate the basic concepts of neural networks in-line with feed forward neural network and its training process along with machine learning classifiers **(Cognitive Knowledge Level: Apply)**
CO 4	Demonstrate and describe the underlying mathematical relationships within and across Machine Learning algorithms and the paradigms of unsupervised learning. **(Cognitive Knowledge Level: Apply)**
CO 5	Demonstrate and illustrate throw to compare various machine learning models along with the application of machine learning in control problems **(Cognitive Knowledge Level: Apply)**

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO4	PO5	PO6	PO7
CO 1	√		√	√			√
CO 2	√	√	√		√	√	
CO 3	√	√	√		√	√	
CO 4	√	√	√		√	√	

CO 5	√	√					√

Assessment Pattern

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

Mark distribution

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

Continuous Internal Evaluation Pattern:

ELECTIVE COURSES Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: 40 marks
Preparing a review article based on peer reviewed Original publications (minimum 10 Publications shall be referred) : 15 marks
Course based task/Project/Seminar/Data Collection and interpretation: 15 marks
Test paper, 1no.: 10 marks
Test paper shall include minimum 80% of the syllabus

End Semester Examination Pattern:

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

minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question paper

QP CODE: PAGES:

Reg No:_______________ Name:_________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

____SEMESTER_____DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221EEE030

Course Name: MACHINE LEARNING

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

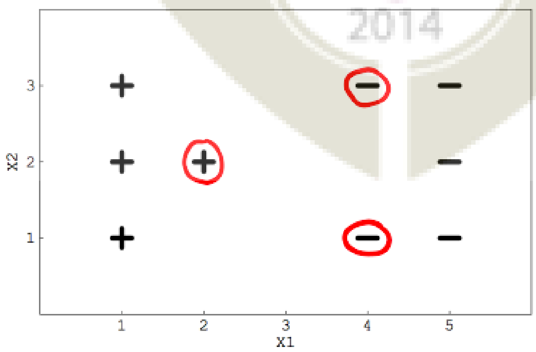
PART A

Answer all Questions. Each question carries 5 Marks

1. Explain how a system can play a game of Chess using reinforcement learning.

2. Suppose you have a dataset with m = 1000000 examples and n = 200000 features for each example. You want to use multivariate linear regression to fit the parameters to our data. Should you prefer gradient descent or the normal equation? Justify your answer.

3. Suppose you are using a Linear SVM classifier with 2 class classification problem and you are given the following data in which some points are circled red that are representing support vectors.



If you remove any one red points from the data. Does the decision boundary will change? Discuss in detail.

4. How can a generative model p(x|y) be used as a classifier? Also explain, why is dimensionality reduction useful?

5. A classifier has a high precision but low recall. What does this mean?

(5x5=25)

PART B

Answer any FIVE Question. Each question carries 7 Marks

6. Define supervised learning? Name and explain with suitable examples, the special cases of supervised learning depending on whether the inputs/outputs are categorical, or continuous.

7. How can you interpret the output of a two-class logistic regression classifier as a probability? Also, In a two-class logistic regression model, the weight vector w = [4, 3, 2, 1, 0]. We apply it to some object that we would like to classify; the vectorized feature representation of this object is x = [−2, 0,−3, 0.5, 3]. What is the probability, according to the model, that this instance belongs to the positive class? Discuss.

8. Consider a support vector machine whose input space is 2-D, and the inner products are computed by means of the kernel K(x, y) = (x.y + 1)2-1, where x.y denotes the ordinary inner product. Show that the mapping to feature space that is implicitly defined by this kernel is the mapping to 5-D given by

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \rightarrow \phi(\mathbf{x}) = \begin{bmatrix} x_1^2 \\ x_2^2 \\ \sqrt{2}\, x_1 x_2 \\ \sqrt{2}\, x_1 \\ \sqrt{2}\, x_2 \end{bmatrix}$$

9. Suppose that we have the following data:

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*
(2,0)	(1,2)	(2,2)	(3,2)	(2,3)	(3,3)	(2,4)	(3,4)	(4,4)	(3,5)

Identify the cluster by applying the k-means algorithm, with k = 2. Try using initial cluster centers as far apart as possible.

10. Explain the various types of regression. Also, ssuppose if you are asked to perform linear regression to learn the function that outputs y, given the D-dimensional input x. You are given N independent data points, and that all the D attributes are linearly independent. Assuming that D is around 100, would you prefer the closed form solution or gradient descent to estimate the regressor?

11. Consider the two dimensional patterns (2, 1), (3, 5), (4, 3), (5, 6), (6, 7), (7, 8). Compute the principal component using PCA Algorithm.

12. (a) Define Precision, Recall, Accuracy and F-measure?

(b)Fill in the missing values in the accompanying three class confusion matrix. Given that model accuracy is 72% and classification error for class 2 is 20%. Find also the precision and recall for class1.

	Predicted		
	Class 1	Class 2	Class 3

EE1

Actual	Class 1	14	2	5
	Class 2	? (x)	40	2
	Class 3	1	?(y)	18

(5x7=35)

Syllabus and Course Plan

Module I (Introduction)(6 hrs)

Introduction to Machine Learning - How do machines learn - Selecting the right features, Understanding data:- numeric variables – mean, median, mode, Measuring spread.

Review of distributions: Uniform and normal. Categorical variables.

Machine learning paradigms-supervised, semi-supervised, unsupervised, reinforcement learning.

Module II (Supervised Learning) (10 hrs)

Supervised Learning - Regression - Linear regression with one variable, Linear regression with multiple variables, solution using gradient descent algorithm and matrix method, basic idea of overfitting in regression.

Linear Methods for Classification- Logistic regression, Perceptron, Naive Bayes, Classification using Decision Trees and Rules - Decision Tree algorithm ID3

Module-III (Neural Networks (NN) and Support Vector Machines (SVM)) (8 hrs)

NN - Multilayer feed forward network, Activation functions (Sigmoid, ReLU, Tanh), Back propagation algorithm.

SVM - Introduction, Maximum Margin Classification, Mathematics behind Maximum Margin Classification, Maximum Margin linear separators, soft margin SVM classifier, non-linear SVM, Kernels for learning non-linear functions, polynomial kernel, Radial Basis Function(RBF).

Module-IV (Unsupervised Learning) (8 hrs)

Clustering - Similarity measures, Hierarchical Agglomerative Clustering, K-means partitional clustering, Expectation maximization (EM) for soft clustering. Dimensionality reduction – Principal Component Analysis, factor Analysis,

Multidimensional scaling, Linear Discriminant Analysis.

Module-V (Classification Assessment and Appplications) (10 hrs)

Classification Performance measures - Precision, Recall, Accuracy, F-Measure, Receiver Operating Characteristic Curve(ROC), Area Under Curve(AUC. Bootstrapping, Cross Validation, Ensemble methods, Bias-Variance decomposition.

Applications to Control Problems: State estimation using neuro observer (single layer and multi layer), kalman filter and reinforcement learning, ;Identification of non-linear dynamical systems using neural networks (state space models and input-output models)

Optimal control problems using support vector machines, regression methods, monte-carlo method, model predictive control and adaptive reinforcement learning

Course Project: Develop a classifier for face detection application or similar simple problems.

COURSE PLAN

No	Topic	No. of Lectures
1	**Introduction to Machine Learning(6 hrs)**	
1.1	Introduction to Machine Learning - How do machines learn -Selecting the right features.	1
1.2	Understanding data:- numeric variables – mean, median, mode, Measuring spread	1
1.3	Review of distributions: Uniform and normal. Categorical variables.	1
1.4	Machine learning paradigms-supervised, semi-supervised, unsupervised, reinforcement learning.	1
1.5	Machine learning paradigms-supervised, semi-supervised, unsupervised, reinforcement learning.	2
2	**Supervised Learning (10 hrs)**	
2.1	Supervised Learning - Regression - Linear regression with one variable, Linear regression with multiple variables.	2
2.2	Solution using gradient descent algorithm and matrix method, basic idea of overfitting in regression	3
2.3	Linear Methods for Classification- Logistic regression, Perceptron,	2
2.4	Naive Bayes, Classification using Decision Trees and Rules - Decision Tree algorithm ID3	3
3	**Neural Networks (NN) and Support Vector Machines (SVM)(8 hrs)**	
3.1	NN - Multilayer feed forward network, Activation functions (Sigmoid, ReLU, Tanh)	2

3.2	Back propagation algorithm.	2
3.3	SVM - Introduction, Maximum Margin Classification, Mathematics behind Maximum Margin Classification, Maximum Margin linear separators, soft margin	2
3.4	SVM classifier, non-linear SVM, Kernels for learning non-linear functions, polynomial kernel, Radial Basis Function(RBF).	2
4	**Unsupervised Learning (8 hrs)**	
4.1	Clustering - Similarity measures, Hierarchical Agglomerative Clustering.	2
4.2	K-means partitional clustering, Expectation maximization (EM) for soft clustering.	2
4.3	Dimensionality reduction – Principal Component Analysis, factor Analysis,	2
4.4	Multidimensional scaling, Linear Discriminant Analysis	2
5	**Classification Assessment and Applications (8 hrs)**	
5.1	Classification Performance measures - Precision, Recall, Accuracy, F-Measure, Receiver Operating Characteristic Curve(ROC), Area Under Curve(AUC. Bootstrapping, Cross Validation, Ensemble methods, Bias-Variance decomposition.	3
5.2	Applications to Control Problems: State estimation using neuro observer (single layer and multi layer), kalman filter and reinforcement learning, ;Identification of non-linear dynamical systems using neural networks (state space models and input-output models)	3
5.3	Optimal control problems using support vector machines, regression methods, monte-carlo method, model predictive control and adaptive reinforcement learning	2

Reference Books

1. Frank Leroy Lewis, Suresh Jagannathan, A. Yeşildirek, Neural Network Control of Robot Manipulators and Non-Linear Systems, Taylor and Francis group, 1999.
2. Frank L. Lewis, Derong Liu, Reinforcement Learning and Approximate Dynamic Programming for Feedback Control, Wiley and IEEE press, 2013
3. Zi-Xing Cai, Intelligent Control: Principles, Techniques and Applications World Scientific, 1997.
4. Bishop, C. M., Pattern Recognition and Machine Learning, Springer, 2006.
5. Alexander S. Poznyak, Edgar N. Sanchez, Wen Yu, Differential Neural Networks for Robust Nonlinear Control Identification, State Estimation and Trajectory tracking, World Scientific, 2001.
6. Alex Smola, S.V.N. Vishwanathan, Introduction to Machine Learning, Cambridge University Press, 2010.
7. Simon Haykins, Neural Networks and Learning Machines, Prentice Hall, 2009.
8. Related Research Articles from Journals and Conferences.

CODE 221EIA002	COURSE NAME EMBEDDED SYSTEMS AND APPLICATIONS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course focuses on the architecture and programming of embedded processors, development of applications using Embedded/Real-Time Operating Systems and deploying the applications on ARM processors.

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

CO 1	Design real time embedded systems by analysing the characteristics of different computing elements in embedded system. (LEVEL 3)
CO 2	Identify the unique characteristics of real time operating systems and evaluate the need for real time operating system (LEVEL 3)
CO 3	Identify and characterize architecture of ARM MCU (LEVEL 3)
CO 4	Apply the knowledge gained for Programming ARM Processor for different applications. (LEVEL 3)
CO 5	Analyse various examples of embedded systems based on ARM processor. (LEVEL 4)

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**
CO 1	3		3	3	2		
CO 2	3		3	3	2		
CO 3	3		3	3	2		
CO 4	3		3	3	2		
CO 5	3		3	3	2		

Assessment Pattern

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

Mark distribution

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

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation: 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College.

There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

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Model Question Paper

Pages **SLOT**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

221EIA002- EMBEDDED SYSTEMS AND APPLICATIONS

Max. Marks: 60 **Time: 2.5 hrs**

	Part A **(Answer all questions)**	**Marks**
1	Differentiate between independent design and codesign concepts	(5)
2	Illustrate with examples the advantages of writing embedded firmware in C.	(5)
3	Compare features of various ARM architectures	(5)
4	Generate an asymmetric square wave at four pins of PORT P0 using software delay	(5)
5	Develop a block schematic diagram for implementing vison-controlled ROBOT application and explain each block	(5)
	Part B **(Answer any five questions)**	
6	Choose appropriate hardware units needed for the following embedded applications a) Robot b) Motor Control and c) Digital camera. Justify your answer,	(7)
7	With a flow chart model illustrate the embedded program development process from high level language to machine level language	(7)
8	Analyse the distinct features of real time operating system that makes it suitable for embedded applications	(7)
9	With the help of a neat diagram explain the architecture ARM processor	(7)
10	Generate PWMs at the six output pins of PWM unit with duty cycles of 40 and 50%	(7)
11	Design an embedded system for Adaptive cruise control and explain the details	(7)

12	Write an embedded C program to interface a single switch and display its status through a relay, Buzzer and LED	(7)

Syllabus

Module 1

Embedded System Organization

Embedded computing – characteristics of embedded computing applications – Introduction to embedded system design- architecture embedded system - Overview of Processors and hardware units in an embedded system – Selection of processor, Memory- I/O devices, Communication protocols SPI, I2C, CAN etc.

Embedded system design and development process- Embedded System On Chip(SOC)- Build process- Challenges in embedded system design, optimising design metrices- Hardware software co-design- Design technologies, Design examples

Software Tools, IDE, Linking and Locating software, Choosing the right platform-Testing, Simulation Debugging Techniques and Tools, Laboratory Tools and target hardware debugging, Emulators

Module 2

Embedded Programming Concepts and RTOS

Programming Concepts -Assembly language, C program elements, Macros and functions, data types data structures Loops and Pointers Object oriented Programming, Embedded programming in C++

Operating System Basics, Types of Operating Systems, Real Time Operating System, Tasks, Process and Threads, Multi processing and Multi-tasking

RTOS Task scheduling models, Handling of task scheduling and latency and deadlines as performance metrics, Co-operative Round Robin Scheduling, Case Studies of Programming with RTOS

Module 3

Architecture and Programming of ARM

Introduction to ARM core architectures, ARM extension, family, Pipeline, memory management, Bus architecture, Programming model, Registers, Operating modes, instruction set, Addressing modes, memory interface.

Programming of ARM, Read Write Memory Access, Basic programming using Online/Offline platforms

Module 4

On Chip Peripherals and Interfacing LPC2148

Internal Architecture of ARM LPC 2148, Study of on-chip peripherals – Input/ output ports, Timers, Interrupts, on-chip ADC, DAC, RTC modules, WDT,PLL, PWM,USB, I2C, SPI, CAN etc

Programming GPIO, Timer programming, PWM Unit programming ARM 9 ,ARM Cortex -M3

Module 5

Embedded Control Applications -Case Studies

Embedded Controller Programmable interface with A/D & D/A interface; Digital voltmeter, -PWM motor speed controller, serial communication interface Feedback control system, relay control unit, driving electrical appliances like motors, bulb, pump, etc.

Case Studies- Embedded system in automobile, Adaptive cruise control, Vison controlled Robot, Ball following Robot

Course Project: Develop an embedded control application using ARM Platform

Course Plan

No	Topic	No. of Lectures
1	**Embedded System Organization (8 hours)**	
1.1	Embedded computing – characteristics of embedded computing applications – Introduction to embedded system design- architecture embedded system - Overview of Processors and hardware units in an embedded system – Selection of processor, Memory- I/O devices	2
1.2	Communication protocols SPI, I2C, CAN etc.	1
1.3	Embedded system design and development process - Embedded System On Chip(SOC),Build process, Challenges in embedded system design, optimising design metrices, Hardware software co-design, Design technologies, design examples	2
1.4	Software Tools, IDE, Linking and Locating software, Choosing the right platform	1
1.5	Testing, Simulation Debugging Techniques and Tools, Laboratory Tools and target hardware debugging, Emulators	2
2	**Programming Concepts and RTOS(10 hours)**	
2.1	Programming Concepts -Assembly language, C program elements, Macros and functions, data types data structures Loops and Pointers.	1
2.2	Object oriented Programming, Embedded programming in C++ and JAVA	2
2.3	Operating System Basics, Types of Operating Systems, Real Time Operating System(RTOS), Tasks, Process and Threads, Multi processing and Multi-tasking	2
2.4	RTOS Task scheduling models, Handling of task scheduling and latency and deadlines as performance metrics	2
2.5	Co-operative Round Robin Scheduling, Case Studies of	2

	Programming with RTOS	
3	**Architecture and Programming of ARM (8 hours)**	
3.1	Features and Architecture of ARM, RISC vs CISC, Modes of operation	2
3.2	ARM assembly language, Addressing Modes, Instruction set	2
3,3	Programming of ARM, ALP, C, Basic programming using Online/Offline platforms	2
3.4	Read Write Memory Access, Multiple register load and store	2
4	**Peripheral programming of ARM (8 hours)**	
4.1	Internal Architecture and features of ARM LPC 214X family	1
4.2	Peripherals inside the chip, GPIO, Timer, Interrupt, UART, PWM	2
4.3	Programming GPPIO, Timer programming	2
4.4	PWM Unit programming, ARM 9, ARM Cortex -M3	2
5	**Embedded Control Applications -Case Studies (8 hours)**	
5.1	Embedded Controller Programmable interface with A/D & D/A interface, Digital voltmeter, -PWM motor speed controller, serial communication interface	2
5.2	Feedback control system, relay control unit, driving electrical appliances like motors, bulb, pump, etc.	2
5.3	Case study -Embedded system in automobile, Adaptive cruise control	2
5.4	Case study -Vison controlled Robot, Ball following Robot	2

Reference Books

1. Jonathan Valvano, Embedded Microcomputer Systems Real Time Interfacing, Third Edition Cengage Learning, 2012
2. Raj Kamal, Embedded Systems-Architecture, programming and design, 3rd edition, TMH.2017
3. Lyla B Das, Embedded Systems an Integrated Approach, Pearson, 2013
4. David E. Simon, An Embedded Software Primer‖, Pearson Education,2000.
5. Steve Heath, Butterworth Heinenann, Embedded systems design: Real world design Newton mass USA 2002

EE1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE100	Advanced Power Semiconductor Devices	PROGRAM ELECTIVE 1	3	0	0	3

Preamble: Power semiconductor devices are recognized as a key component for all power electronic systems. This course explores the underlying physics and electrical characteristics of power semiconductor devices. The course includes the study of basic silicon devices and the new generation wide band gap devices. After the completion of the course, students will be able to select suitable power semiconductor devices and design gate drive & protection circuits.

Course Outcomes:

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

CO 1	Develop an in-depth knowledge about important Silicon (Si) power semiconductor devices.
CO 2	Analyse the characteristics and operational features of the selected power semiconductor device.
CO 3	Investigate the properties of wide bandgap devices for power electronic applications.
CO 4	Familiarize the students with advanced power electronic devices for different applications.
CO 5	Design gate driver and protection circuits for power electronic switching devices.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	2	3	2	2	2	1
CO 2	3	2	3	2	2	2	1
CO 3	3	2	3	3	2	3	1
CO 4	3	3	3	3	3	2	1
CO 5	3	2	3	2	2	3	1

PROGRAM OUTCOMES – PO

Outcomes are the attributes that are to be demonstrated by a graduate after completing the programme

PO1: An ability to independently carry out research/investigation and development work in engineering and allied streams

PO2: An ability to communicate effectively, write and present technical reports on complex engineering activities by interacting with the engineering fraternity and with society at large.

PO3: An ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

EE1

PO4: An ability to apply stream knowledge to design or develop solutions for real world problems by following the standards

PO5: An ability to identify, select and apply appropriate techniques, resources and state-of-the-art tool to model, analyse and solve practical engineering problems.

PO6: An ability to engage in life-long learning for the design and development related to the stream related problems taking into consideration sustainability, societal, ethical and environmental aspects

PO7: An ability to develop cognitive load management skills related to project management and finance which focus on Entrepreneurship and Industry relevance.

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	40 %
Analyse	30 %
Evaluate	20 %
Create	10%

Mark distribution

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

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks

- Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred) : 15 marks
- Course based task/Seminar/Data collection and interpretation : 15 marks
- Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

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

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Syllabus and Course Plan (For 3 credit courses, the content can be for 40 hrs).

MODULE	COURSE CONTENT (40 hrs)	HRS
I	**Power switching devices- overview**- ideal and typical power devices -characteristics- static and dynamic – unipolar and bipolar power devices - conduction and switching losses- thermal protection- heat sink selection- EMI due to switching- reduction of EMI **Silicon Power Diodes**- Types, forward and reverse characteristics, switching characteristics -losses- ratings –schottky diodes. **Gate Turnoff Thyristor (GTO)** - Basic structure and operation - comparison with thyristors- switching Characteristics - turn-on and Turn-off Transients - gate drive requirements- snubber requirements **Integrated gate-commutated thyristors (IGCTs)-** device types- operation- turn on and turn off behaviour- applications	8
II	**Current-Controlled Devices:** BJTs- Constructional features and operation, static characteristics, switching characteristics- Secondary Breakdown - Safe Operating Area - Darlington Configuration- Comparison with GTO **Voltage-controlled Devices:** Power MOSFETs and IGBTs- basic device physics- principle of operation- construction, types, static and switching characteristics.	8
III	**Wide band-gap devices** – Introduction - advantages over silicon devices – properties of wide band-gap devices - power density of wide bandgap devices- comparison- applications **Silicon carbide (SiC) power diodes-** Advantages- features- properties- comparison with Si power diodes **-** SiC Shottky diode- advantage **Silicon Carbide BJT** – Structure – Operation – Static and Dynamic Characteristics. **Silicon Carbide MOSFET** – Planar Power MOSFETs – Trench Gate Power MOSFETs – Structure – static and dynamic characteristics.	8

IV	**Silicon Carbide IGBT:** n-Channel Asymmetric Structure - Optimized n-Channel asymmetric structure - p-Channel asymmetric structure- blocking characteristics- On-state voltage Drop - turn-off characteristics- switching energy - losses- maximum operating frequency **Gallium Nitride devices** – Vertical Power Hetero junction Field Effect Transistor (HFETs) – Lateral Power Hetero junction Field Effect Transistor (HFETs) - High Electron Mobility Transistors (HEMT) - Static and dynamic characteristics	**8**
V	**Gate drive and Protection Circuits:** Gate drive circuits for transistors, MOSFET, IGBT, SiC MOSFET and IGBT and GaN devices– challenges and design - necessity of isolation- pulse transformer- optocoupler - overvoltage, over current and gate protection- turn-on and turn-off snubber circuit design **Power modules**- typical internal structure- design challenges- features- design for reliability enhancement- intelligent power modules (IPM)- features- study of typical power modules and IPM	**8**

Course Plan

No	Topic	No. of Lectures
1	**Power switching devices- overview**- ideal and typical power devices -characteristics- static and dynamic – unipolar and bipolar power devices - conduction and switching losses- thermal protection- heat sink selection- EMI due to switching- reduction of EMI **Silicon Power Diodes**- Types, forward and reverse characteristics, switching characteristics -losses- ratings –Schottky diodes **Gate Turnoff Thyristor (GTO)** - Basic structure and operation - comparison with thyristors- switching Characteristics - turn-on and Turn-off Transients - gate drive requirements- snubber requirements **Integrated gate-commutated thyristors (IGCTs)-** device types- operation- turn on and turn off behaviour- applications	
1.1	**Power switching devices- overview**- ideal and typical power devices -characteristics- static and dynamic	1
1.2	Unipolar and bipolar power devices - conduction and switching losses- thermal protection- heat sink selection-	1
1.3	EMI due to switching- reduction of EMI	1

1.4	**Silicon Power Diodes-** Types, forward and reverse characteristics, switching characteristics -losses- ratings – Schottky diodes	1
1.5	**Gate Turnoff Thyristor (GTO)** - Basic structure and operation - comparison with thyristors- switching Characteristics - turn-on and Turn-off transients - gate drive requirements- snubber requirements	2
1.6	**Integrated gate-commutated thyristors (IGCTs)-** device types- operation- turn on and turn off behaviour- applications	2
2	**Current-Controlled Devices:** BJTs- Constructional features and operation, static characteristics, switching characteristics- Secondary Breakdown - Safe Operating Area - Darlington Configuration - Comparison with GTO **Voltage-controlled Devices:** Power MOSFETs and IGBTs- basic device physics- principle of operation- construction, types, static and switching characteristics.	
2.1	**Current-Controlled Devices:** BJTs- Constructional features and operation, static characteristics, switching characteristics	2
2.2	Secondary Breakdown in BJT - Safe Operating Area - Darlington Configuration - Comparison with GTO	2
2.3	**Voltage-controlled Devices:** Power MOSFETs and IGBTs- basic device physics- principle of operation-	2
2.4	Construction, types, static and switching characteristics	2
3	**Wide band-gap devices** – Introduction - advantages over silicon devices – properties of wide band-gap devices - power density of wide bandgap devices- comparison- applications **Silicon carbide (SiC) power diodes-** Advantages- features- properties- comparison with Si power diodes **-** SiC Schottky diode- advantages **Silicon Carbide BJT** – Structure – Operation – Static and Dynamic Characteristics. **Silicon Carbide MOSFET** – Planar Power MOSFETs – Trench Gate Power MOSFETs – Structure – static and dynamic characteristics.	
3.1	**Wide band-gap devices** – Introduction - advantages over silicon devices – properties of wide band-gap devices - power density of wide bandgap devices- comparison- applications	2
3.2	**Silicon carbide (SiC) power diodes-** Advantages- features- properties- comparison with Si power diodes**-** SiC Shottky diode- advantages	2
3.3	**Silicon Carbide BJT** – Structure – Operation – Static and	2

	Dynamic Characteristics	
3.4	**Silicon Carbide MOSFET** – Planar Power MOSFETs – Trench Gate Power MOSFETs – Structure – static and dynamic characteristics	2
4	**Silicon Carbide IGBT:** n-Channel Asymmetric Structure - Optimized n-Channel asymmetric structure - P-Channel asymmetric structure-blocking characteristics- On-state voltage Drop - turn-off characteristics-switching energy - losses- maximum operating frequency **Gallium nitride devices** –Vertical Power Hetero junction Field Effect Transistor (HFETs) – Lateral Power Hetero junction Field Effect Transistor (HFETs) - High Electron Mobility Transistors (HEMT) - Static and dynamic characteristics.	
4.1	**Silicon Carbide IGBT:** n-Channel Asymmetric Structure - Optimized n-Channel asymmetric structure -	2
4.2	P-channel asymmetric structure- blocking characteristics-On-state voltage Drop - turn-off characteristics-	1
4.3	Switching energy - losses- maximum operating frequency	1
4.4	**Gallium nitride devices** – Vertical Power Hetero junction Field Effect Transistor (HFETs) – Lateral Power Hetero junction Field Effect Transistor (HFETs)	2
4.5	High Electron Mobility Transistors (HEMT) - Static and dynamic characteristics	2
5	**Gate drive and Protection Circuits:** Gate drive circuits for transistors, MOSFET, IGBT, SiC MOSFET and IGBT and GaN devices– challenges and design - necessity of isolation- pulse transformer- optocoupler - overvoltage, over current and gate protection- turn-on and turn-off snubber circuit design **Power modules**- typical internal structure- design challenges- features-design for reliability enhancement- intelligent power modules (IPM)-features- power modules and IPM	
5.1	**Gate drive and Protection Circuits:** Gate drive circuits for transistors, MOSFET, IGBT, SiC MOSFET and IGBT and GaN devices– challenges and design	2
5.2	Necessity of isolation- pulse transformer- optocoupler overvoltage, over current and gate protection	1
5.3	turn-on and turn-off snubber circuit design	2
5.3	**Power modules**- typical internal structure- design challenges-features- design for reliability enhancement	2
5.4	Intelligent power modules (IPM)- features- study of typical	1

	power modules and IPM	

REFERENCES:

1) B. W. Williams, “Power Electronics- Devices, Drivers, Applications and passive components”, Macmillan, 2005

2) B. Jayant Baliga, “Fundamentals of Power Semiconductor devices”, Springer, 2019

3) Francesco Iannuzzo, “Modern Power Electronic Devices_ Physics, Applications, and Reliability”, Institution of Engineering & Technology (IET), 2020

4) Mohan, Undeland and Robins, “Power Electronics- Concepts, Applications and Design”, John Wiley and sons, Singapore, 2000

Model Question paper

APJ Abdul Kalam Technological University

First Semester M. TECH Degree Examination Month & Year

221EEE100– ADVANCED POWER SEMICONDUCTOR DEVICES

Time : 3 hrs. Max.Marks:60

PART A (5X5=25 marks)

1) Discuss the factors to be considered for the selection and power handling capability of power semiconductor devices

2) What are the differences between current controlled and voltage controlled devices in terms of gate drive design? Explain

3) What are wide band gap devices and what are the advantages over silicon devices? Explain

4) What are the differences between Silicon Carbide and Gallium Nitride Transistors in terms of gate drive design? Explain

5) Explain the design of IGBT driver circuit with over current protection.

PART B

Answer any 5 questions

6) (a) Draw the reverse recovery characteristics of a power diode and explain the terms (i) Reverse recovery time (ii) Peak inverse current and (iii) S-Factor. Also derive the expressions for reverse recovery time and peak inverse current. (7 marks)

7) Explain the EMI phenomenon in power electronic drives and discuss the various methods to reduce it. (7 marks)

8) (a) Explain the switching characteristics of P channel MOSFET (4 marks)

(b) Calculate the total power loss for the MOSFET having the following parameters:

V_{DS} = 120V, I_D = 4A, t_r = 80ns, t_f = 120ns, I_{DSS} = 2mA, $R_{DS(on)}$ = 0.2Ω, duty cycle D=50%, and $f_{switching}$ = 45kHZ. (3 marks)

9) Explain the constructional features, characteristics and gate drive requirements of IGCT (7 marks)

10) Explain the static and switching characteristics of GaN switching devices. (7 marks)

11) Explain the snubber requirements in GTO (7 marks)

12) Design a gate drive circuit for Silicon carbide MOSFET and describe the design challenges to be considered. (7 marks)

221EIA001	ANALOG AND DIGITAL INSTRUMENTATION	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: To provide a clear knowledge on analog to digital converter

- To acquire clear knowledge in data acquisition systems
- To provide knowledge in interfacing and data transmission systems
- To provide knowledge in various buses and process measurements

Course Outcomes:

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

CO 1	Explain the basic principle of analog and digital instrumentation system.
CO 2	Design data acquisition system
CO 3	Design and solve PLC based automation system
CO 4	Explain different networking topologies for data communication in process industries.
CO 5	Apply HART and Field bus protocols for process industries.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	✓						
CO 2	✓						
CO 3	✓						
CO 4	✓						
CO 5	✓						
CO 6	✓						

Assessment Pattern

Bloom's Category	**End Semester Examination(marks in %)**
Remember	15
Understand	20
Apply	25
Analyse	
Evaluate	

EE1

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed

original publications (minimum 10 publications shall be referred): 15 marks

Course based task/Seminar/Data collection and interpretation: 15 marks

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students).

Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question paper

QP CODE:

Reg No.:_______________

Name:______________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER M.TECH. DEGREE EXAMINATION,

MONTH & YEAR

Course Code: 222EIA001

ANALOG AND DIGITAL INSTRUMENTATION

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer ***ALL*** questions; each question carries 5 marks)

1. Compare at least 5 important points between Analog Instrumentation and Digital instrumentation.
2. Discuss the factors to be considered for their selection of ADC in data acquisition system.
3. Mention the three different data coding Standards and compare their performance
4. Expalin the basic requirements of field bus standards.
5. What are the advantages of PC based Instrumentation system.

PART B

(Answer ***any FIVE*** questions; each question carries 7 marks)

6. Draw and explain the block diagram of analog instrumentation systems. Also write the advantages and disadvantages of analog instrumentation systems.
7. What is meant by data logger? Discuss the functions and characteristics of a data logger?.
8. Draw the block schematic of a 8 channel data acquisition system and
   1. Explain the subsystem requirement
   2. Explain the timing requirements based on the data rate.
9. Explain the architecture of a PLC system. Where it is used and mention its advantages.
10. Compare Standard ETHERNET with Industrial ETHERNET Configuration.
11. Explain the role of various field buses in an automation process.
12. Explain HART communication protocol and explain the benefits of HART communication.

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EE1

Syllabus and Course Plan

No	Topic	No. of Lectures
1	Introduction to instrumentation and process automation	
1.1	Introduction to instrumentation and process automation. Details of Analog Instrumentation systems, Block diagram, examples, Advantages and disadvantages of Analog Instrumentation system	3
1.2	Introduction to Digital Instrumentations system: Block diagram and sub systems-Comparison of analog and digital instrumentation system	2
1.3	Design of digital instrumentation systems and standards. (interface standard, communication protocols).	2
2	Data acquisition systems	
2.1	Data acquisition systems Objective - Building blocks of Automation systems	1
2.2	Multi, Single channel Data Acquisition systems	1
2.3	PC based DAS, Data loggers- Sensors based computer data systems	2
	Design a data acquisition circuit (working project)	2
3		
3.1	Data coding methods - error detection, correction and encryption	2
3.2	Fiber Optic transmission - Optical fiber Cables - light sources and detectors	2
3.3	Architecture of a PLC – Analog and digital types of I/O modules	2
3.4	PLC system memories - Program and data organization inside a PLC - Networking of multiple PLC.	3
4	**Parallel Port Buses**	
4.1	Field bus –Introduction - General field bus architecture	1
4.2	Basic requirements of field bus standard-field bus topology - Interoperability – interchangeability	3
4.3	Mod bus, GPIB, IEEE-488, VME, VXI, CAN bus- Basics, Message transfer, Fault confinement	4
4.4	Standard ETHERNET and Industrial ETHERNET Configuration	2
5	PC based instrumentation	
5.1	PC based instrumentation Introduction - control system interface	1
5.2	PC based industrial process measurements like flow, temperature, pressure and level development system	2
5.3	PC based Instruments development system. Basic requirements of Instrument, interrupt and data handshaking	2
5.4	Evolution of signal Standard - HART Communication protocol	1
5.5	Communication modes – HART Commands – HART and the OSI model.	2

EE1

Reference Books

1. Kevin M. Daugherty, Analog - Digital conversion: A Practical Approach, Tata McGraw- Hill International Editions, 1995

2. N. Mathivanan, Microprocessors, PC Hardware and Interfacing, Prentice Hall India, 2003.

3. Krishna Kant, Computer- based Industrial Control, Prentice Hall India Pvt. Ltd., 2004.

4. H. S. Khalsi, Electronic Instrumentation, Technical Education Series Tata McGraw-Hill, 2004.

5. Frank Petruzella, Programmable Logic Controllers, 5th Edition, McGraw-Hill, 2017. Romilly Bowden, HART Application Guide, HART Communication Foundation, 1999.

221EEE049	ROBOTIC SYSTEMS AND CONTROL	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: To familiarize robotic configurations and develop kinematic and dynamic models to plan the trajectories of mobile robots with suitable controllers.

Course Outcomes:

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

CO 1	Familiarise with anatomy, specifications and standard robot configurations
CO 2	Obtain the kinematic model of a robotic manipulator and to plan trajectories for a robot
CO 3	Develop dynamic model for robots
CO 4	Familiarise with different mobile robot configurations
CO 5	Design controllers for robotic manipulators
CO 6	Design controllers for mobile robots

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3						
CO 2	3						
CO 3	3						
CO 4	3						
CO 5	3		3	3	2		
CO 6	3		3	3	2		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	30
Analyse	30
Evaluate	30
Create	10

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Model Question Paper **D**

221EEE049 - ROBOTIC SYSTEMS AND CONTROL

Answer all full questions from PART A and any 5 full questions from PART B

Limit answers to the required points.

Max. Marks: 60 Duration: 2.5 hours

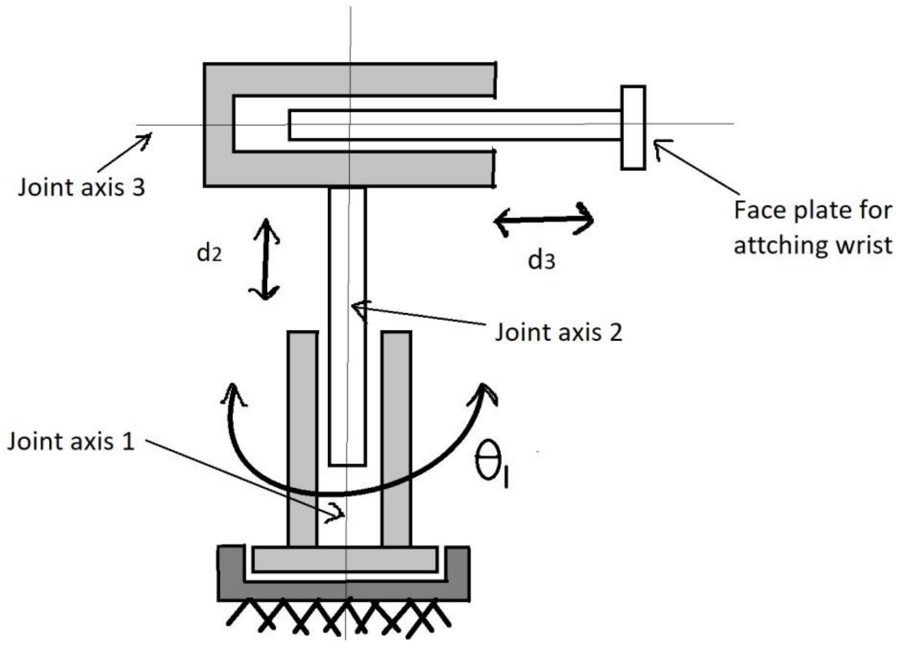
PART A

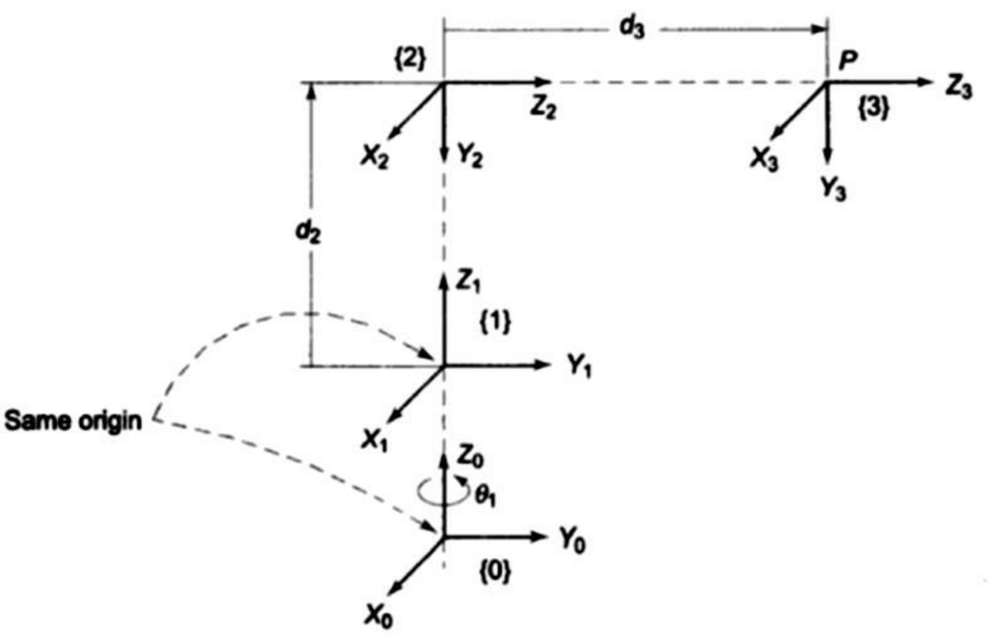
1		Write a short note on the basic building blocks of a robotic manipulator.	(5)
2		A single-link robot with a rotary joint is motionless at θ = 15 degrees. It is desired to move the joint in a smooth manner to θ = 75 degrees in 3 seconds. Determine the cubic polynomial to interpolate a smooth trajectory that accomplishes this motion and brings the manipulator to rest at the goal. Also obtain the velocity and acceleration profiles of the joint as a function of time.	(5)
3		Obtain the kinematic model of a differentially driven mobile robot and compute the state space model of this system with x, y, θ as states and left wheel and right wheel velocities as control inputs.	(5)
4		Write a short note on the computed torque control scheme of robotic manipulators.	(5)
5		How will you drive a steered robot to a specified destination [xg, yg]? With the help of block schematic explain the control scheme.	(5)

PART B

6	a.	List and explain specifications of a robotic manipulator in detail.	(4)
	b.	Briefly explain the classification of robotic manipulators based on motion control methods.	(3)

EE1
7 For the following cylindrical robot arm, compute the position and orientation of the tool tip. (7)



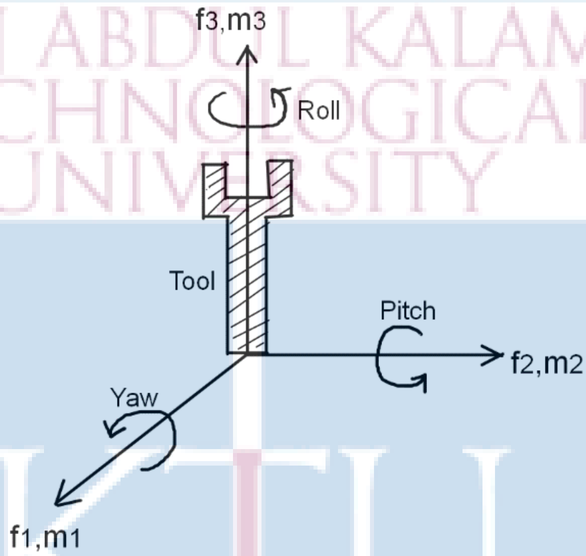


8 a. Suppose the point P at the tool tip shown in the below figure has mobile coordinates $[P]^M = [\ 7,3,2\ ]^T$ and is subjected to the transformations described next. Find the coordinates of the point relative to the fixed reference $F = \{f^1, f^2, f^3\}$ frame at the conclusion of transformations. (4)

i. Rotation of 90 degree about f^3 axis,

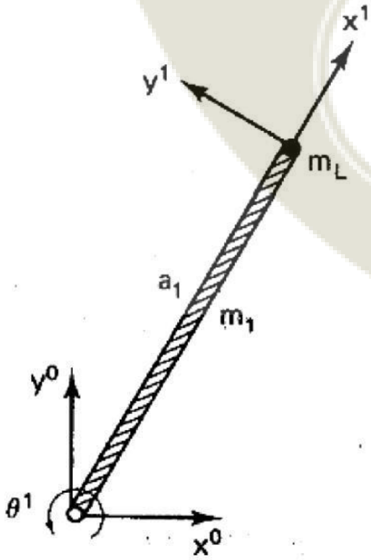
ii. Followed by a rotation of 90 degree about the f^2axis,

iii. Followed by a translation of [4, -3, 7].



b. Differentiate between forward kinematics and inverse kinematics of a robot arm. (3)

9 Obtain the dynamic model of the single link manipulator of link length $a_1$and mass m_1 handling a load of mass m_L. (7)



10 Explain in detail about any one linear control scheme of robotic manipulator. (7)

11 Suppose a robotic manipulator is to be designed to erase a white board. Which control scheme be used? Explain. (7)

EE1

12	Design a controller for a steered mobile robot to follow a line in the plane given by $ax + by + c = 0$. With the help of a suitable block diagram explain how the controller can be implemented.	(7)

Syllabus

Module I:

Introduction

Robots, Robotics; Types of Robots- Manipulators, Mobile Robots-wheeled & Legged Robots, Aerial Robots; Anatomy of a robotic manipulator-links, joints, actuators, sensors, controller; open kinematic vs closed kinematic chain; degrees of freedom; Robot considerations for an application- number of axes, work volume, capacity & speed, stroke &reach, Repeatability, Precision and Accuracy, Operating environment, point to point control or continuous path control.

Robot configurations-PPP, RPP, RRP, RRR; features of SCARA, PUMA Robots; Classification of robots based on motion control methods and drive technologies.

Module II

Kinematics and Motion Planning

Robot Coordinate Systems- Fundamental and composite rotations, homogeneous co-ordinates and transformations, Kinematic parameters, D-H representation, Direct Kinematics. The Arm equation- forward Kinematic analysis of a typical robots upto 3 DOF.

Motion Planning- joint space trajectory planning-cubic polynomial, linear trajectory with parabolic blends; Cartesian space planning, Point to point vs continuous path planning.

Module III

Modelling of Robots

Dynamics- Dynamic model of a robot using Lagrange's equation, dynamic modelling of 1DOF robot, including motor and gearbox, 2R planar manipulator.

Basic understanding of Differential-Drive WMR, Car-Like WMR, Three-Wheeled Omnidirectional Mobile Robot, Kinematic model of a differential drive and a steered mobile robot.

Module IV

Control of robotic manipulators

Necessity of a control system in a robot, block diagram typical robot control system, position control, force control.

PID control, PD gravity control, Computed torque control, Variable Structure control, Impedance control, digital control of a single link manipulator.

Case study- Feedback control of a single link manipulator using MATLAB. (Assignment/demo only)

Module V

Control of mobile robots

Control of mobile robots- Control of differential drive robot and steered robot based on its kinematic model, Control of differential drive robot to move to a point, follow a line, follow a trajectory, to achieve an orientation. Control of a steered robot to move to a point, follow a line, follow a trajectory, to achieve an orientation.

Case study- design and implementation of a differential drive robot capable of moving to a point, following a line and following a path using MATLAB (Assignment/demo only)

References

1. Robert. J. Schilling , "Fundamentals of robotics – Analysis and control", Prentice Hall of India 1996.
2. R K Mittal and I J Nagrath, "Robotics and Control", Tata McGraw Hill, New Delhi,2003.
3. Introduction to Robotics by S K Saha, Mc Graw Hill Eduaction
4. Introduction to Robotics (Mechanics and control), John. J. Craig, Pearson Education Asia 2002.
5. Ashitava Ghosal, "Robotics-Fundamental concepts and analysis", Oxford University press.
6. Peter Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB
7. Introduction to Autonomous Mobile Robots , R Siegwart, IR Nourbakhsh, D Scaramuzza, , MIT Press, USA, 2011.

Course plan

No	Topic	No. of Lectures
1	**Introduction**	
1.1	Robots, Robotics; Types of Robots- Manipulators, Mobile Robots- wheeled & Legged Robots, Aerial Robots;	2
1.2	Anatomy of a robotic manipulator-links, joints, actuators, sensors, controller; open kinematic vs closed kinematic chain; degrees of freedom;	2
1.3	Robot considerations for an application- number of axes, work volume, capacity& speed, stroke &reach, Repeatability, Precision and Accuracy, Operating environment, point to point control or continuous path control.	2
1.4	Robot configurations-PPP, RPP, RRP, RRR; features of SCARA, PUMA Robots; Classification of robots based on motion control methods and drive technologies.	3
2	**Kinematics and Motion Planning**	
2.1	Robot Coordinate Systems- Fundamental and composite rotations, homogeneous co-ordinates and transformations	2.5
2.2	Kinematic parameters, D-H representation, Direct Kinematics. The Arm equation- forward Kinematic analysis of a typical robots upto 3 DOF.	4
2.3	Motion Planning- joint space trajectory planning-cubic polynomial, linear trajectory with parabolic blends; Cartesian space planning, Point to point vs continuous path planning.	2.5
3	**Modelling of Robots**	
3.1	Dynamics- Dynamic model of a robot using Lagrange's equation, dynamic modelling of 1DOF robot, including motor and gearbox, 2R planar manipulator.	3

3.2	Basic understanding of Differential-Drive WMR, Car-Like WMR, Three-Wheeled Omnidirectional Mobile Robot	2
3.3	Kinematic model of a differential drive and a steered mobile robot.	2
4	**Control of robotic manipulators**	
4.1	Necessity of a control system in a robot, block diagram typical robot control system, position control, force control.	2
4.2	PID control, PD gravity control, Computed torque control, Variable Structure control, Impedance control, digital control of a single link manipulator.	5
4.3	Case study- Feedback control of a single link manipulator using MATLAB. (Assignment/demo only)	1
5	**Control of mobile robots**	
5.1	Control of mobile robots- Control of differential drive robot and steered robot based on its kinematic model, Control of differential drive robot to move to a point, follow a line, follow a trajectory, to achieve an orientation.	4
5.2	Control of a steered robot to move to a point, follow a line, follow a trajectory, to achieve an orientation.	2
5.3	Case study- design and implementation of a differential drive robot capable of moving to a point, following a line and following a path using MATLAB (Assignment/demo only)	1

CODE 221EEE054	Modelling and Simulation of Aerospace Systems	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: To apply the basic knowledge of flight controls in the development of aerospace vehicle simulation models and critically evaluate its performance by integrating guidance and sensor subsystems.

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

CO 1	Apply the basic knowledge of flight controls and the development of models
CO 2	Develop aircraft simulation models and evaluate its performance
CO 3	Conduct critical reviews of simulations by a comparison with real aircraft models
CO 4	Analyse performance of aerospace systems by integrating the guidance and sensor subsystems

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3		3	3	3		3
CO 2	2	2	3	3	3		2
CO 3	3	2	3	3	3		3
CO 4	3		3	3	3		2

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40

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

End Semester Examination Pattern: 60

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

Model Question paper

PART A

*(Answer **All** Questions)* (5X5 = 25 Marks)

1. A T-37 aircraft is executing a loop at the following conditions:

   Euler angles: ψ = 0 deg, Θ = 30 deg, Φ = 0 deg

   The pilot observes a pure pitch rate at a constant velocity in the body axis system:

$$\bar{\omega}_B = \begin{Bmatrix} 0 \\ 0.1 \\ 0 \end{Bmatrix}_B \text{rad/s} \qquad \bar{V}_B = \begin{Bmatrix} 200 \\ 0 \\ 0 \end{Bmatrix}_B \text{ft/s}$$

   Find the acceleration in Earth-Fixed reference frame.

2. Given the following vectors, find the Inertial acceleration in Body axis system:

$$\bar{a}_I = \dot{\bar{V}}_B + \bar{\omega}\, x\, \bar{V}_B$$

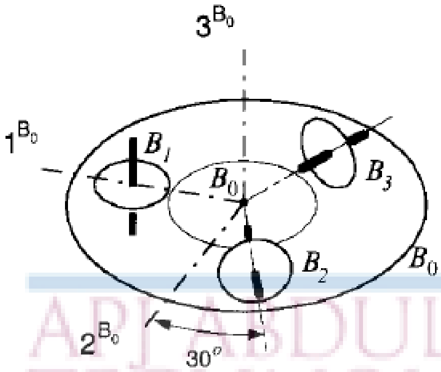
$$\dot{\bar{V}}_B = \begin{Bmatrix} 10 \\ 0 \\ 0 \end{Bmatrix} \frac{\text{ft}}{\text{s}^2} \qquad \bar{\omega} = \begin{Bmatrix} 0 \\ 0 \\ 0.3 \end{Bmatrix} \frac{\text{rad}}{\text{s}} \qquad \bar{V}_B = \begin{Bmatrix} 300 \\ 0 \\ 0 \end{Bmatrix} \frac{\text{ft}}{\text{s}}$$

3. The Hubble Space Telescope, B_0, is stabilized by three control moment gyros(CMG) B1, B2 and B3. The CMG mass centres have the same distance x from The center B0 and are equally spaced, starting with gyro #1 aligned with the 1^{B0} axis of the telescope. The directions of the spin axes are shown in the Figure. The given quantities are: mass of telescope, m_0; mass of one CMG, m; Spin MOI of CMG, I_s; transverse MOI of CMG, I; angular rate of CMG with respect to B0, ω; distance of CMG from B0, x; Moment of inertia of telescope is given by

$$[I_{B_0}^{B_0}]^{B_0} = \begin{bmatrix} I_0 & 0 & 0 \\ 0 & I_0 & 0 \\ 0 & 0 & I_{03} \end{bmatrix}$$

   Velocity of the telescope with respect to inertial frame, $[\overline{v_{B_0}^I}]^I = [0 \;\; v_0 \;\; 0]$;

   angular velocity of telescope wrt to inertial frame, $[\overline{\omega^{B_0 I}}]^I = [0 \;\; 0 \;\; \omega_0]$. For the cluster, k = 0,1,2,3, determine in tensor format, the linear momentum.



4. The attitude of a missile B0 is controlled by its swivelling rocket engine B1 with thrust $[\bar{t}]^{B_1} = [T \ \ 0 \ \ 0]$ and known swivel angle δ(t). Neglecting all other forces and moments, determine the differential eqaution that governs the pitch angular velocity $[\overline{\omega^{B_0 I}}]^{B_0} = [0 \ \ q \ \ 0]$ of the missile. The mass properties are given
$$m^{B_0}, [I_{B_0}^{B_0}]^{B_0} = \text{diag}(I_1, I_2, I_3)$$
$$m^{B_1}, [I_{B_1}^{B_1}]^{B_1} = \text{diag}(J_1, J_2, J_3)$$

5. Using the thrust and induced power computations, find an exact solution for thrust and power for the special case of hover over a fixed point with no wind.

PART B

*(Answer **Any Five** Questions)* (7X5 = 35 Marks)

6. Show that, for a quaternion product, the norm of the product is equal to the product of the individual norms.

7. An airfoil is tested in a subsonic wind tunnel. The lift is found to be zero at a geometrical angle of attack $\alpha = -1.5°$. At $\alpha = 5°$, the lift coefficient is measured as 0.52. Also, at $\alpha = 1°$ and $7.88°$, the moment coefficients about the center of gravity are measured as −0.01 and 0.05, respectively. The center of gravity is located at 0.35*c*. Calculate the location of the aerodynamic center and the value of *Cmac*.

8. Using the first-order flapping dynamics for the stabilizer bar presented, derive a corresponding expression for the main rotor flapping angles using the approximation that the main rotor time constant is negligibly small. That is, we treat the main rotor flapping as responding instantly to input.

9. Derive the pitch attitude equations of the space shuttle $\boldsymbol{B_o}$ as it launches a satellite $\boldsymbol{B_I}$. Assume that the release is parallel and in the opposite direction of the space shuttle's 3rd axis. The satellite's displacement vector from the shuttle's centre of mass $\boldsymbol{B_o}$ is $[\overline{s_{B_1 B_0}}]^{B_0} = [-a \ \ 0 \ \ \eta]$, where *a* is a

positive constant and $\eta(t)$ a known function of t. Determine the differential equation of motion of the shuttle's pitch angular velocity.

10. Develop three dimensional equations of motion of space vehicle in Cartesian and polar co-ordinates.

11. List out necessary steps to model and simulate the subsystems of three stage rocket ascent to 300 km orbit. All the necessary assumptions can be made.

12. Develop Pseudo-five degrees of freedom model for a space vehicle system.

Syllabus

Module I

Kinematics and dynamics of aircraft motion: Rotational kinematics – translational kinematics – rigid body dynamics. Aircraft modelling: forces and moments – nonlinear aircraft model – linear models and stability derivatives. Modeling, Design and Simulation tools: State-space models - transfer function models – numerical solution – simulation of aircraft models – steady state flight – aircraft dynamic behaviour – feedback control. Aircraft rigid body modes – handling qualities – stability augmentation – control augmentation – autopilots – nonlinear simulation

Module II

Three-Degrees of freedom Simulation: Equations of Motion – Subsystem Models – Atmosphere and Gravity models, Hypersonic Vehicle Simulation, Three-stage Rocket Simulation.

Module III

Five–Degrees of Freedom Simulation: Pseudo–Five-Degrees of freedom – Coordinate transformation and angular rates – Kinematics – Equations of motion with rotating and flat Earth – Subsystem models. Trimmed aero dynamics for tetragonal missiles and planar aircrafts. Autopilots.

Module IV

Guidance – implementation of line guidance, Sensors – Kinematic and Dynamic seekers – Radar and electro optical sensors- Simulation of Air intercept missile – Short range air to air intercept missile – Cruise missiles.

Module V

Modeling and Simulation of Miniature Aerial Vehicles, Forces and Moments – modelling rotor flapping, Motor modelling – Small aerobatic airplane model – Simulations, Quadrotor model – Small helicopter model - Simulations

Course Plan

No	Topic	No. of Lectures
1		
1.1	Kinematics and dynamics of aircraft motion: Rotational kinematics – translational kinematics – rigid body dynamics	2
1.2	Aircraft modelling: forces and moments – nonlinear aircraft model – linear models and stability derivatives	2
1.3	Modelling, Design and Simulation tools: State-space models - transfer function models – numerical solution – simulation of aircraft models – steady state flight – aircraft dynamic behaviour – feedback control	3
1.4	Aircraft rigid body modes – handling qualities – stability augmentation – control augmentation – autopilots – nonlinear simulation	2
2	Three-Degrees of freedom Simulation	
2.1	Equations of Motion – Subsystem Models – Atmosphere and Gravity models	3
2.2	Hypersonic Vehicle Simulation	2
2.3	Three-stage Rocket Simulation	2
3	Five–Degrees of Freedom Simulation	
3.1	Pseudo–Five-Degrees of freedom – Coordinate transformation and angular rates – Kinematics – Equations of motion with rotating and flat Earth – Subsystem models	3
3.2	Trimmed aerodynamics for tetragonal missiles and planar aircrafts	2
3.3	Autopilots	3
4		
4.1	Guidance – implementation of line guidance	3
4.2	Sensors – Kinematic and Dynamic seekers – Radar and electro optical sensors	2
4.3	Simulation of Air intercept missile – Short range air to air intercept missile – Cruise missiles	3
5	Modelling and Simulation of Miniature Aerial Vehicles	
5.1	Forces and Moments – modelling rotor flapping	4
5.2	Motor modelling – Small aerobatic airplane model - Simulations	2
5.3	Quadrotor model – Small helicopter model - Simulations	2

Reference Books

1. B. L. Stevens, F. L. Lewis, and E. N. Johnson, “Aircraft Control and Simulation”, Wiley Publishers, Third Edition, 2015.

2. Peter H. Zipfel, “Modelling and Simulation of Aerospace Vehicle Dynamics”, AIAA Education Series, 3rd Edition, 2014

3. Blakelock, J. H, “Automatic Control of Aircraft and Missiles”, 2nd Edition, Wiley, 1991.

4. Thomas Yechout, “Introduction to Aircraft Flight Mechanics”, A1AA Education Series, 2003.

5. E. Bryson, “Control of Spacecraft and Aircraft”, Princeton University Press, 1994

6. B. Wie, “Space Vehicle Dynamics and Control”, AIAA Education Series, 2008

221EIA003	IMAGE PROCESSING	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: This course helps the learners understand the core concepts and applications of Digital Image Processing. It covers Digital Image Fundamentals, Image Transforms, Image Enhancement in Spatial and Frequency Domain, Image Restoration & Image Segmentation and Morphological Operations & Representation and Description. The learners will be able to develop new algorithms, tools, and application software for real-world applications involving image processing.

Course Outcomes:

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

CO 1	Explain the concepts of image formation and the basis of digital image processing. **(Cognitive Knowledge Level: Understand)**
CO 2	Demonstrate the role of image transforms in representing, highlighting, and modifying image features. **(Cognitive Knowledge Level: Apply)**
CO 3	Solve image enhancement problems using spatial and frequency domain techniques. **(Cognitive Knowledge Level: Apply)**
CO 4	Make use of the concept of image restoration and image segmentation techniques in real-world problems. **(Cognitive Knowledge Level: Apply)**
CO 5	Interpret morphological operations, image representation, and description techniques. **(Cognitive Knowledge Level: Understand)**

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	✓	✓					
CO 2	✓	✓			✓		
CO 3	✓	✓	✓				
CO 4	✓	✓	✓	✓	✓	✓	
CO 5	✓	✓					

Assessment Pattern

Bloom's Category	**End Semester Examination (%)**
Apply	40
Analyse	30
Evaluate	30
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed

original publications (minimum 10 publications shall be referred): 15 marks

Course based task/Seminar/Data collection and interpretation: 15 marks

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

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

Note: The marks obtained for the ESE for an elective course shall not exceed 20%over the average ESE mark % for the core courses. ESE marks awarded to as student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question Paper

QP CODE:

Reg No.:_______________

Name:______________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER M.TECH. DEGREE EXAMINATION,

MONTH & YEAR

Course Code: 221EIA003

IMAGE PROCESSING

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer ***ALL*** questions; each question carries 5 marks)

1. Explain a Simple Image Formation Model with the help of a neat diagram.
2. State the advantages of Discrete Cosine Transform over Discrete Fourier Transform.
3. Describe the role of Unsharp masking with its applications
4. Explain any two types of thresholding techniques. Describe the threshold detection algorithm using Otsu's method.
5. Illustrate Huffman coding.

PART B

(Answer ***any FIVE*** questions; each question carries 7 marks)

6. Describe arithmetic, logical and geometrical operations on Image.
7. You are given a 4 X 4 image patch Compute 2D DCT for the image patch. Reconstruct the original image patch by neglecting the last four coefficients in 2D DCT. Comment on the observed result.

$$\begin{bmatrix} 12 & 4 & 2 & 6 \\ 5 & 10 & 12 & 24 \\ 6 & 8 & 10 & 12 \\ 14 & 12 & 8 & 10 \end{bmatrix}$$

8. Explain the output and application of the following point processing techniques
   (i) Range Compression (ii) Bit Extraction (iii) Thresholding

9. Explain Image degradation model with the help of a neat diagram.

10.Describe in detail any two boundary representation schemes and illustrate with examples.

11.Illustrate the split and merge algorithm for image segmentation using neat sketches.

12.Explain and compare the basic frequency domain filters for image sharpening

****

Syllabus and Corse Plan

No	Topic	No. of Lectures
1	**Digital Image Fundamentals**	
1.1	Elements of Visual Perception, A Simple Image Formation Model, Spatial and Intensity Resolution. Image Interpolation	2
1.2	Classification of Digital Images. Image Types. Image Storage Mechanisms.	2
1.3	Arithmetic and Logical Operations. Geometric Spatial Transformations and Image Registration	2
1.4	Image File Formats. Colour Fundamentals and Colour Models.	2
2	**Image Transforms**	
2.1	Basic concept of spatial domain and frequency domain, Unitary transform,	2
2.2	Discrete Fourier Transform- 2D DFT, 4 order DFT Transform coefficients, Forward and inverse transform	2
2.3	Discrete Cosine Transform- 2D DCT, 4 order DCT Transform Coefficients	2
2.4	Forward and Inverse DCT, Hadamard Transform.	2
3	**Image enhancement**	
3.1	Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering– Smoothing and Sharpening Spatial Filtering	2
3.2	Frequency Domain: Introduction to Fourier Transform– Smoothing and Sharpening	2
3.3	Frequency domain filters – Ideal, Butterworth and Gaussian filters,	2
3.4	Homomorphic filtering, Color image enhancement.	2
4	**Image Restoration & Image Segmentation**	

4.1	Image degradation model, Noise models, Mean Filters, Order Statistic filter, Adaptive filters	2
4.2	Edge Detection, gradient operators, Laplace operators and zero crossings	2
4.3	Thresholding, Basic Global Thresholding, Optimum global thresholding using Otsu method, Multiple thresholds, Variable thresholding, Multivariable thresholding.	3
4.4	Region-Based Approach to Segmentation	1
5	**Image compression and recognition**	
5.1	Need for data compression, Huffman, Run Length Encoding, Shift codes, Arithmetic coding, JPEG standard, MPEG	3
5.2	Boundary representation, Boundary description, Fourier Descriptor	2
5.3	Regional Descriptors – Topological feature, Texture - Patterns and Pattern classes - Recognition based on matching	3

Text Books

1. Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing (English) 3rd Edition, Pearson India, 2013
2. A K. Jain, Fundamentals of digital image processing, Prentice Hall of India, 1989.

Reference Books

1. Al Bovik, The Essential Guide to Image Processing, Academic Press, 2009.
2. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing, Analysis, and Machine Vision, Thomson Learning, 2008.
3. S Jayaraman, S Esakkirajan and T Veerakumar, Digital Image Processing, McGraw Hill Education, 2009.
4. Kenneth R. Castleman, _Digital Image Processing‘, Pearson, 2006.
5. Rafael C. Gonzalez, Richard E. Woods, Steven Eddins, Digital Image Processing using MATLAB‘, Pearson Education, Inc., 2011.
6. D.E. Dudgeon and RM. Mersereau, Multidimensional Digital Signal Processing‘, Prentice Hall Professional Technical Reference, 1990.
7. William K. Pratt, Digital Image Processing‘, John Wiley, New York, 2002

221EIA005	BIOSIGNAL PROCESSING	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: This course aims to provide students with fundamental concepts of physiological signals and to develop student's ability to analyze the signals to solve problems.

Course Outcomes:

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

CO 1	Develop knowledge about the human physiology system.
CO 2	Design filters for noise and artifact removal from biomedical signals
CO 3	Apply various methods to analyze biomedical signal characteristics in different domains
CO 4	Develop ability to model simple physiological systems

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3				
CO 2	2			2			
CO 3	2				2		
CO 4				2	2		

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer-reviewed Original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data

collection and interpretation : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

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

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question paper

E **No. of Pages: 2**

Reg No.: ……..………..……..…….. **Name: ……..………..……..………..………..…**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Branch: Electrical and Electronics Engineering

Stream(s):

1. **Industrial Instrumentation and Control**
2. **Instrumentation and Control**
3. **Control Systems**

Course Code & Name: 221EIA005 Bio signal Processing

Limit answers to the required points.

Max. Marks: 60 Duration: 2.5 hours

PART A

Answer all questions, each carries 5 marks.

1. A nerve cell has an action potential of a duration of 10 ms including the refractory period. What is the maximum rate (in pulses per second) at which this cell can transmit electrical activity? (5)

2. The adaptive 60-Hz filter calculates the function (5)

$$f(nT + T) = [x(nT + T) - e(nT + T)] - [x(nT) - e(nT)]$$

It adjusts the future estimate e(nT + T) based on whether this function is greater than, less than, or equal to zero. Use a drawing and explain why the function could not be simplified to $f(nT + T) = x(nT + T) - e(nT + T)$

3. Prove that the autocorrelation function (ACF) $\varphi_x(\tau)$ of any function x(t) is maximum at $\tau = 0$ (5)

4. Explain the relationship between heart sound and heart blood pressure variation with the help of a graph containing both pressure variation and heart sounds. (5)

5. The autoregressive model coefficients of a signal are $a_0 = 1$, $a_1 = 1$, $a_2 = 0.5$. What is the transfer function of the model? Draw the pole-zero diagram of the model. What are the resonance frequencies of the system? (5)

PART B

Answer any five full questions from each module, each carries 7 marks.

6. Draw a typical PCG (heart sound signal) waveform over one cardiac cycle indicating the important component waves, their typical durations, and the typical intervals between them. Label each wave or interval with the corresponding cardiac event or activity. (7)

7. A biomedical signal is expected to be band-limited to 100 Hz, with significant components of interest up to 80 Hz. However, the signal is contaminated with a periodic artifact with a fundamental frequency of 60 Hz and significant third and fifth harmonics. A researcher samples the signal at 200 Hz without pre-filtering the signal. Draw a schematic representation of the spectrum of the signal and indicate the artifact components. Label the frequency axis clearly in Hz. What kind of a filter would you recommend to remove the artifact? (7)

8. A certain signal analysis technique requires the following operations in order: (a) differentiation, (b) squaring, and (c) lowpass filtering with a filter H(w). Considering a generic signal x(t) as the input, write the time-domain and frequency-domain expressions for the output of each stage. Will changing the order of the operations change the final result? Why (not)? (7)

9. A rhythmic episode of a theta wave in an EEG signal is approximated by a researcher to be a sine wave of frequency 5 Hz. The signal is sampled at 100 Hz. Draw a schematic representation of the ACF of the episode for delays up to 0.5s. Label the time axis in samples and in seconds. Draw a schematic representation of the PSD of the episode. Label the frequency axis in Hz. (7)

10. Outline a signal processing algorithm to identify S1 and S2 in a PCG signal, and further segment the PCG signal into its systolic and diastolic parts. The ECG and carotid pulse signals are available for reference. (7)

11. Investigate features of the EMG that make the signal nonstationary. Propose signal processing strategies to track the time-varying characteristics of the signal. Under what conditions can the signal be partitioned into quasi-stationary segments? What are the physiological features that you would be able to derive from each segment? (7)

12. A model is described by the relationship (7)

$$x(n) = -0.5y(n - 1) - y(n - 2) + x(n) + 0.5x(n - 1) - x(n - 2),$$

where x(n) is the input and y(n) is the output. What is the type of this system among AR, MA, and ARMA systems? What is the model order? What is its transfer function? Draw the pole-zero diagram of the system. Comment upon the stability of the system.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Introduction to bio signals:**	
1.1	Physiology: Cell and its structure	1
1.2	Resting and Action Potentials	1
1.3	Nervous system – CNS –PNS – Nerve	1
1.5	Origin and Waveform Characteristics of Basic Biomedical Signals Electrocardiogram (ECG), Electroencephalogram (EEG), Electromyogram (EMG), Phonocardiogram (PCG), Event-Related Potentials (ERPS),	3
1.6	Objectives of Biomedical Signal Analysis, Challenges in Biomedical Signal Analysis, Computer-Aided Diagnosis	2
2	**Filtering for Removal of Artifacts from Bio Signal:**	
2.1	Physiological Interference	1
2.2	Stationary and Nonstationary Processes	1
2.3	Noises in Bio signals: Random and Structured Noise	1
2.4	Noises and Artifacts Present in EEG and ECG	2
2.5	Time domain filtering	3
2.6	Frequency Domain Filtering	2
2.7	Optimal Filtering: The Weiner Filter, Adaptive Filtering Selecting Appropriate Filter	2
3	**Signal Processing and Event Detection in Biomedical Signals (EEG and ECG)**	
3.1	EEG Signal and Its Characteristics,	1
3.2	EEG Rhythms, Waves and Transients,	1
3.3	EEG Analysis, Linear Prediction Theory,	1
3.4	Autoregressive Method, Sleep EEG;	1
3.5	Detection of P, Q, R, S and T Waves in ECG,	1
3.6	Detection of Waves and Transients,	1
3.7	Correlation Analysis and Coherence Analysis of EEG Channels	2
4	Heart sound and Murmurs	
4.1	Heart Sounds and Murmurs, Characterization of Nonstationary Signals and Dynamic Systems,	2
4.2	Short-Time Fourier Transform,	1
4.3	Considerations in Short-Time Analysis and Adaptive Segmentation.	3
5	**Modelling of Biomedical Systems**	
5.1	Modelling of Biomedical Systems: Motor unit firing pattern,	1
5.2	Cardiac rhythm, Formants and pitch of speech,	1
5.3	Point process, Parametric system modelling,	2
5.4	Autoregressive model.	2

Reference Books

1. Rangayyan, R.M., 2015. Biomedical signal analysis (Vol. 33). John Wiley & Sons.
2. Reddy, D.C., 2005. Biomedical signal processing: principles and techniques. McGraw-Hill
3. Tompkins, W.J., 1993. Biomedical digital signal processing. Editorial Prentice Hall.
4. Sörnmo, L. and Laguna, P., 2005. Bioelectrical signal processing in cardiac and neurological applications (Vol. 8). Academic Press.
5. Suresh R Devasahayam 2013, Signals and Systems in Biomedical Engineering, 2nd Edition Springer

221EEE056	GAME THEORY	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: The course introduces the basic concepts of game theory, and its applications.

Course Outcomes:

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

CO 1	Acquire fundamental knowledge of the game theory formulations like strategic form, extensive form, zero sum, non-zero sum games etc.
CO 2	Understand the type of game theoretic formulation to be utilized in solving various problems
CO 3	Compute pure strategy Nash equilibria.
CO 4	Compute mixed strategy Nash equilibria.

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**
CO 1				2			
CO 2				2	3		
CO 3	2			3	2		
CO 4				3	2		

Assessment Pattern

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

Mark distribution

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

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks

Preparing a review article based on peer reviewed

Original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question. Students should answer all questions.

Part B will contain 7 questions with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

Part A

(Answer all questions, each carry 5 marks, 5 * 5 = 25 marks)

1. What are the different classifications of games?

2. There are two players, Chooser (player I) and Hider (player II). Hider has two gold coins in his back pocket. At the beginning of a turn, he puts his hands behind his back and either takes out one coin and holds it in his left hand (strategy L1) or takes out both and holds them in his right hand (strategy R2). Chooser picks a hand and wins any coins the hider has hidden there. She may get nothing (if the hand is empty), or she might win one coin, or two. Model the game between chooser and hider.

3. Show the relation between reaction curves, best responses and pure strategy Nash equilibrium for an N-player non-zero sum game.

4. John has no job and might try to get one. Or he might prefer to take it easy. The government would like to aid John if he is looking for a job but not if he stays idle. The payoffs are

government	jobless John: try	jobless John: not try
aid	(3,2)	$(-1,3)$
no aid	$(-1,1)$	(0,0)

Find the Nash equilibria.

5. Explain any one algorithm to compute pure strategy Nash equilibrium for finite number of strategies.

Part B

(Answer any 5 questions, each carry 7 Marks, 5 * 7 = 35 marks)

6. Differentiate strategic form and extensive form games with an example each.

7. Find the pure strategy Nash equilibria for two player non-zero sum game with player 1 (P1) and player 2 (P2) payoffs are given as follows.

P1 = [1 0; 2 -1], P2 = [2 3; 1 0]

8. Find the value of the zero-sum game given by the following matrix, and determine all the optimal strategies of both players.

A= [3 0; 0 3; 2 2]

9. Find the saddle point in mixed strategy for the following zero sum game with the payoff matrix given below

Payoff matrix = [1 3 0; 6 2 7]

10. State and prove the existence theorem of mixed strategy Nash Equilibrium using fixed point theorem.

11. Illustrate with an example that every finite game of perfect information has Nash equilibrium

12. Discuss the complexity of computing pure strategy and mixed strategy Nash equilibrium.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Introduction to Game Theory**	
1.1	*Notions in Game Theory:* Definition of a Game - Strategic Interactions – Strategic Form Games – Preferences – Utilities – Rationality – Intelligence – Classification of Games	4
1.2	*Strategic Form and Extensive Form Games:* Strategic Form Games: Definition and Examples – Extensive Form Games: Definition and Examples.	4
2	**Zero Sum and Non-zero-Sum Games**	
2.1	*Zero Sum Games and Non-zero-Sum Games:* Definition and Examples of Zero sum and Non-zero sum games in Strategic and Extensive Form	4
2.2	*Dominant Strategy Equilibria:* Strong Dominance and Weak Dominance Equilibria: Definition and Examples.	3
3	**Pure Strategy Nash Equilibrium**	
3.1	*Pure Strategy Nash Equilibrium:* Definition and Illustrative Examples of Pure Strategy Nash Equilibria in Zero Sum and Non-zero-Sum Games – Best Responses and Reaction Curves	4
3.2	Nash Equilibrium as a Fixed Point - Saddle Point and Pure Strategy Nash Equilibria - Existence of Pure Strategy Nash Equilibria – Interpretations of Nash Equilibria.	4
4	**Mixed Strategy Nash Equilibrium**	
4.1	*Mixed Strategy Nash Equilibrium:* Mixed Strategies – Mixed Strategy Nash Equilibrium in Zero sum and Non-zero sum games - Maxmin and Minmax Values in Mixed Strategies	5
4.2	Existence of Mixed Strategy Nash Equilibrium – Graphical Approach to compute Mixed Strategy Nash	4

	Equilibrium.	
5	**Computation of Nash Equilibrium**	
5.1	Example for Computing Nash Equilibria: Pure and Mixed Strategy Nash Equilibria – General Algorithm For Finding Nash Equilibria of Finite Strategic Games	5
5.2	Complexity of Computing Nash Equilibria – Introduction of software tools for computing Nash Equilibria.	3

Reference Books

1. Y Narahari – Game Theory and Mechanism Design – IISc Press and World Scientific, 2014
2. Anna R. Karlin and Yuval Peres – Game Theory, Alive (Available Online https://homes.cs.washington.edu/~karlin/GameTheoryBook.pdf)
3. Osborne, M.J. An Introduction to Game Theory, Oxford University Press, 2004
4. Tamer Basar – Dynamic Non-cooperative Game Theory, SIAM Publishers, 1998
5. Gibbons, R. A Primer in Game Theory, Pearson Education, 1992
6. Drew Fudenberg and Jean Tirole – Game Theory, MIT Press 1991

CODE 221EEE055	COURSE NAME ADVANCED CONTROL SYSTEM DESIGN	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: To give a foundation to design robust controllers for multivariable feedback systems and to develop fractional order models and controllers for physical systems.

Course Outcomes:

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

CO 1	Design robust controller for feedback systems.
CO 2	Analyse multivariable feedback systems.
CO 3	Design state feedback controllers for multivariable systems.
CO 4	Develop fractional order models for physical systems.
CO 5	Design fractional order state feedback controllers.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	3	3	2	
CO 2			3	3	3	2	
CO 3			3	3	3	2	
CO 4			3	3	3	2	
CO 5			3	3	3	2	

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

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

Model Question paper

Pages **SLOT**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

221EEE055: Advanced Control System Design

Max. Marks: 60 **Time: 2.5 hrs**

	Part A **(Answer all questions)**	**Marks**
1	Explain with examples the basic rules for evaluating transfer function matrices for MIMO systems.	(5)
2	Explain the different ways of representing uncertainties in a system.	(5)
3	List out the algebraic and control properties of RGA.	(5)
4	Explain the general control configuration for MIMO systems with uncertainty	(5)
5	Explain non- Gaussian probability density function and the development of corresponding FO model	(5)
	Part B **(Answer any five questions)**	
6	Describe the loop shaping technique for a closed loop transfer function.	(7)
7	Explain the superiority of fractional order control over the conventional integer order control in terms of closed-loop performance with a suitable example.	(7)
8	Explain in detail the procedure for analyzing input-output controllability for MIMO systems.	(7)
9	Using singular value decomposition method, obtain the singular values of the system matrix A= $\begin{bmatrix} 3 & 1 & 1 \\ -1 & 3 & 1 \end{bmatrix}$	(7)
10	Given the system , where $A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$ and $B = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 1 \end{bmatrix}$ Design a state feedback controller such that the closed loop poles are located at -1, -2 and -3.	(7)

11	Compute the condition number and RGA for a system with $G = \begin{bmatrix} 87.8 & -86.4 \\ 108.2 & -109.6 \end{bmatrix}$	(7)
12	Consider a system with three inputs m1=20, m2=40 and m3=70, with system constants T1=423, T2=293, T3=293, C1=10, C2=4, C3=0. The three outputs are given as y1= m1+m2+m3 y2=(T1m1+T2m2+T3m3)/y1 y3=(C1m1+C2m2+C3m3)/y1 Calculate the RGA using steady state gain matrix method and use it to determine the best control scheme for the system.	(7)

Syllabus

Module 1

Feedback Control:

One degree-of-freedom controller, Two degrees-of-freedom and feedforward controllers-Shaping of open loop and closed loop transfer functions, Loop shaping for disturbance rejection, Loop shaping design with examples

Module 2

Multivariable Feedback Control:

Transfer functions for MIMO systems, Singular Value Decomposition - interpretation of singular values and associated input directions with physical applications, Relative Gain Array – Physical interpretation with examples Control Properties of RGA

Module 3

Pole Placement for MIMO systems-Controllability of MIMO systems-Robust Eigen structure Assignment – MIMO design case studies

Module 4

Fractional-order Modeling :

Analysis of fractional-order modeling of: electrical circuit elements like inductor, capacitor, electrical machines like transformer, induction motor and transmission lines, FO modeling of viscoelastic materials, concept of fractional damping-Models of basic circuits and mechanical systems using FO elements, Concept of anomalous diffusion, non-Gaussian probability density function and the development of corresponding FO model-A brief overview of FO models of biological systems.

Module 5

Fractional-order Control

Detailed discussion and analysis of superiority of FO control over the conventional IO control in terms of closed-loop performance, robustness and stability, FO PID control, Design of FO state-feedback controllers

Course Plan

No	Topic	No. of Lectures
1	Feedback Control	
1.1	One degree-of-freedom controller, Two degrees-of-freedom and feedforward controllers	2
1.2	Shaping of open loop and closed loop transfer functions, Loop shaping for disturbance rejection	2
1.3	Loop shaping design with examples	3
1.4	Inverse-based controller design with examples	3
2	Multivariable Feedback Control	
2.1	Transfer functions for MIMO systems	2
2.2	Singular Value Decomposition - interpretation of singular values and associated input directions with physical applications	3
2.3	Relative Gain Array – Physical interpretation with examples	3
2.4	Control Properties of RGA	2
3	Pole Placement for MIMO systems	
3.1	Controllability of MIMO systems	2
3.2	Robust Eigen structure Assignment – MIMO design case studies	3
4	Fractional-order Modeling	
4.1	Analysis of fractional-order modeling of: electrical circuit elements like inductor, capacitor, electrical machines like transformer, induction motor and transmission lines, FO modeling of viscoelastic materials, concept of fractional damping	2
4.2	Models of basic circuits and mechanical systems using FO elements, Concept of anomalous diffusion, non- Gaussian probability density function and the development of corresponding FO model	3
4.3	A brief overview of FO models of biological systems.	2
5	Fractional-order Control	
5.1	Detailed discussion and analysis of superiority of FO control over the conventional IO control in terms of closed-loop performance, robustness and stability	2
5.2	FO PID control	3

5.3	Design of FO state-feedback controllers	3

Reference Books

1. S Skogestad and I. Postlethwaite, Multivariable Feedback Control, Analysis and design, second edition. New York: Wiley, 2005

2. U. Mackenroth, Robust Control Systems Theory and Case studies, Springer-Verlag, Berlin, Heidelberg, New York:, 2004

3. J. M. Maceijowski, Multi-Variable Feedback Design, Addision-Wesely Pub, 1989

4. R. Caponetto, G. Dongola, L. Fortuna, and I. Petras. Fractional Order Systems: Modeling and Control Applications. World Scientific, Singapore, 2010.

5. K. S. Miller and B. Ross. An Introduction to the Fractional Calculus and Fractional Differential Equations. John Wiley & Sons, USA, 1993.

6. C. A. Monje, Y. Q. Chen, B. M. Vinagre, D. Xue, and V. Feliu. Fractional-order Systems and Control: Fundamentals and Applications Springer-Verlag London Limited, UK, 2010

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221LEE004	Digital and Simulation Lab	LAB 1	0	0	2	2

Preamble: This Laboratory Course provides a platform for modelling and analysis of linear and nonlinear systems with the help of hardware and software tools in the control framework.

Prerequisite: Basic knowledge of modern control theory and simulation tools

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

CO 1	Develop the mathematical model of a given physical system by conducting appropriate experiments.
CO 2	Analyse the performance and stability of physical systems using classical and advanced control approaches.
CO 3	Design controllers for physical systems to meet the desired specifications.
CO 4	Design Observers for feedback systems
CO 5	Apply appropriate techniques and modern tools for modelling and analysis of physical systems

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	3			
CO 2			3	3	2		
CO 3			3	3	2		
CO 4			3	3	3		

Reference Books

1. Richard C. Dorf and Robert H. Bishop, Modern Control Systems, Eleventh Edition, Pearson Education 2009.

2. Katsuhiko Ogata, Modern Control Engineering, Fourth Edition, Pearson Education,2002.

EE1

List of Exercises/Experiments:

Simulation tools like MATLAB/ SCILAB or equivalent may be used.

10 experiments are mandatory.

Experiment No.	Name of the experiment
1	**Control Design by PID (Eg. DC Motor speed control)** Objective: Derive the transfer function of Armature Controlled DC motor Study the effect of tuning of PID controller on the above system using MATLAB/SIMULINK
2	**PMDC motor modeling, identification, speed control** Objective: 1. Develop a physics-based model for a PMDC motor. 2. For the PMDC motor develop a model based on system identification using open-loop (OL) step response. 3. Design a speed controller for the physics-based model using Bode plot based loop-shaping techniques. Simulate this controller
3	**Ziegler-Nichols tuning of speed controller of PMDC motor** Objective: To apply a Ziegler-Nichols tuning (ZNT) methods to tune the parameters of a PID controller of the speed of a PMDC motor.

4	**PMDC speed control** Objective: To control the speed of the PMDC motor using feedback of current by simulation and experiment.
5	**PMDC armature current control** Objective: To control the armature current of the PMDC motor at the desired value by simulation and experiment.
6	**Control Design by pole-placement (Eg. DC Motor speed control).** Objective: A. Derive the state space model of Armature Controlled DC motor. B. Obtain the state space model in MATLAB C. Analyse the open loop stability, controllability and observability. D. Design a controller by pole-placement technique and verify.
7	**Disturbance observer** Objective: To implement a disturbance observer (DOB) for a PMDC motor.
8	**Disturbance observer without feedback of current** Objective: To build and test a PMDC motor speed control system that uses a disturbance

	observer (DOB) but does not use the feedback of armature current.
9	**Stability analysis of nonlinear autonomous systems using phase plane.** Objective: A. Simulate the given nonlinear autonomous system using state space model B. Theoretically determine the various singular points and verify the same from phase portraits using simulations. C. Analyse the stability of the system at various singular points from phase portraits.
10	**Closed loop performance of inverted pendulum.** Objective: Study of performance characteristics of inverted pendulum by experiment. Determine the various unknown parameters of an inverted pendulum experimentally. Obtain the non-linear and linearised models. Design implement and analyse the performance of the system with various state feedback controllers while regulation/tracking
11	**Performance analysis of magnetic levitation system.** Objective: Study of performance of magnetic levitation system by experiment. Understand the dynamics of a magnetic levitation system. Design implement and analyse the performance of this experimental system with various loop controllers while tracking in presence/absence of disturbance
12	**Closed loop performance of Twin rotor system** Objective: Study of performance characteristics of Twin rotor system by experiment.

13	**Mass Spring Damper system** Objective: Understand the dynamics and determine the various unknown parameters of a mass spring damper system experimentally and obtain transfer function/ state space models. Design implement and analyse the performance of the system with various state feedback controllers while regulation and tracking