SEMESTER 2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222TEE100	**Computational Techniques in Electrical Engineering**	**Discipline Core -2**	**3**	**0**	**0**	**3**

Preamble:

Numerical computational techniques are indispensable for computing applications in electrical engineering systems. This course is designed with the objective of providing a foundation to the theory behind numerical computation and optimization techniques in electrical engineering systems. This course will equip the students with mathematical framework for the numerical computation and optimization techniques necessary for various computing applications in engineering systems.

Course Outcomes:

After completing the course the student will be able to

CO 1	Apply numerical techniques to find the roots of non-linear equations and solution of system of linear equations.
CO 2	Apply numerical differentiation and integration for electrical engineering applications
CO 3	Apply and analyze numerical techniques of solution to differential equation of dynamical systems
CO 4	Formulate optimization problems and identify a suitable method to solve the same
CO 5	Solve optimization problems in Electrical Engineering using appropriate optimization techniques

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	2	
CO 2	3		3	3	3	2	
CO 3	3		3	3	3	2	
CO 4	3		3	3	3	2	
CO 5	3		3	3	3	2	
CO 6							

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40%

Analyse	40%
Evaluate	20%
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

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

End Semester Examination Pattern: 60 marks

Part A: 5 numerical/short answer questions with 1 question from each module, (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.

Each question can carry 5 marks.

Part B: 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

SLOT A

APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH &YEAR

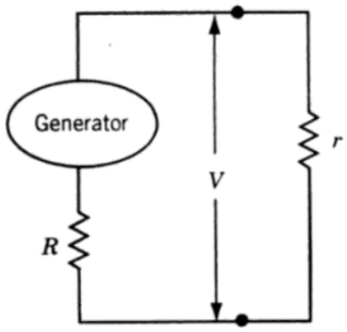
Course code: **222TEE100**

Course Name: **Computational Techniques in Electrical Engineering**

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

PART A

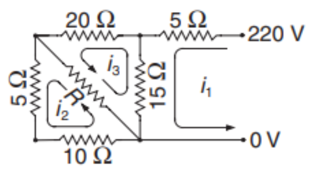
Answer all Questions. Each question carries 5 Marks

1	What is condition number of a matrix. Use condition number to check whether the following matrix is ill-conditioned. $$A = \begin{bmatrix} 1 & 1/2 & 1/3 \\ 1/2 & 1/3 & 1/4 \\ 1/3 & 1/4 & 1/5 \end{bmatrix}$$
2	Given the points $(0,0), \left(\frac{\pi}{2}, 1\right), (\pi, 0)$ satisfying the function $y = \sin x \ (0 \leq x \leq \pi)$, determine the value of $y(\frac{\pi}{6})$ using the cubic spline approximation.
3	Solve the boundary value problem defined below using finite difference method. Compare the solution obtained at y(0.5) with the exact value for h=0.5 and h=0.25. $$y'' - y = 0, \quad y(0) = 0, y(1) = 1$$
4	An electric generator has an internal resistance of R ohms and develops an open circuit voltage of V volts. Find the value of the load resistance r for which power delivered by the generator will be a maximum.  Electric generator with load
5	In which context we can use optimization methods like genetic algorithms and simulated annealing?

PART B

Answer any 5 Questions. Each question carries 7 Marks

6	The electrical network shown can be viewed as consisting of three loops. Apply Kirchoff's law to each loop yields and compute the loop currents i_1, i_2 and i_3 using LU factorization method, for $R = 10\ \Omega$



7 Find the zero of y(x) from the following data:

x	0	0.5	1	1.5	2	2.5	3
y	1.8421	2.4694	2.4921	1.9047	0.8509	−0.4112	−1.5727

Use Lagrange's interpolation over (a) three; and (b) four nearest-neighbor data points.

8 A second order system is defined by:

$$y'' = -\frac{19}{4}y - 10y', \quad y(0) = -9, y'(0) = 0$$

a. Find the analytical solution for the above system using the eigen values of the system
b. Show from (a) that the system is moderately stiff and estimate h_{max}, the largest value of h for which the Runge–Kutta method would be stable.
c. Confirm the estimate by computing y(1) with $h \approx h_{max}/2$ and $h \approx 2\, h_{max}$.

9 Faraday's law characterizes the voltage drop across an inductor as $V_L = L\frac{di}{dt}$, where V_L is the voltage drop (V), L is the inductance (in henrys (H)), i is the current (in Amps), and t is the time (in secs). Determine the voltage drop as a function of time from the following data for an inductance of 4 H.

Time, t (secs)	0	0.1	0.2	0.3	0.5	0.7
Current, i (Amps)	0	0.1	0.32	0.56	0.84	2.0

10 Is this a linear or nonlinear programming problem?

Maximize $Z = 3x_1^2 - 2x_2$

Subject to

$$2x_1 + x_2 = 4$$

$$x_1^2 + x_2^2 \leq 40$$

$$x_1, x_2 \geq 0 \quad \text{and are integers.}$$

Solve this problem by a suitable classical method.

11 Minimize $f(x_1, x_2) = x_1 - x_2 + 2x_1^2 + 2x_1x_2 + x_2^2$ from the starting point $X_1 = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$ using Powell's method.

12 Minimize $f(X) = (x_1 - 1)^2 + (x_2 - 5)^2$ subject to

	$-x_1^2 + x_2 \leq 4$ $-(x_1 - 2)^2 + x_2 \leq 3$ Starting from the point $X_1 = \begin{Bmatrix} 1 \\ 1 \end{Bmatrix}$ and using Zoutendijk's method. Complete two one-dimensional minimization steps.

Syllabus

Module 1

Systems of Linear Algebraic Equations*:* Uniqueness of Solution, Ill conditioning and norms**;** Methods of Solution: Gaussian elimination – LU factorization – Matrix inversion – Gauss-Siedel iteration – least squares method**;** Eigen value problems - Power method for eigen values – Tridiagonalization and QR factorization

Module 2

Interpolation and Curve Fitting*:* Lagrange's Method, Newton's Method, Cubic Spline**;** Least-Squares Fit, Weighting of Data - Weighted linear regression**;** Roots of Equations: Newton–Raphson Method for systems of equations**;** Numerical differentiation - finite difference and first central difference approximations**;** Numerical integration - trapezoidal and Simpson's rule

Module 3

Solution to differential equations*:* Initial Value Problems - Taylor Series Method, Euler Method, Runge–Kutta Methods-Second-Order and Fourth Order; Stability and Stiffness;

Two-Point Boundary Value Problems*:* Shooting Method and finite difference method (Concept only)

Case Study*:* MATLAB/C/ Python programming for solution to differential equations. Two-Point Boundary Value Problems - Shooting Method (Demo/Assignment only)

Module 4

Optimisation problem, Formulation of optimisation problems and linear optimization - Review only.

Classical Optimization Techniques Single variable optimization, Multivariable optimization with equality constraints- Direct substitution, method of Lagrange multipliers, Multivariable optimization with equality constraints- Kuhn-Tucker conditions.

Non-linear Programming: Unconstrained Optimization Techniques Direct Search Methods: Random search methods, Grid search method, Univariate method, Hookes and Jeeves' method, Powell's method; Indirect Search Methods: Steepest descent method, Fletcher-Reeves method, Newton's method

Module 5

Nonlinear Programming: Constrained Optimization Techniques Direct search methods: Random search methods, Basic approach in methods of feasible directions, Zoutendijk's method of feasible directions, Rosen's gradient projection method, Generalized Reduced gradient method, Sequential quadratic programming.

Recent developments in optimization techniques: Genetic Algorithm, Simulated Annealing , Neural Network based optimization, Particle Swarm Optimization, Ant colony Optimization.

Case studies- Power system optimization, Optimal control problem, Electrical machine design optimization, Optimal design of Power Electronic converter- **Assignment/Demo only**

References

1. Erwin Kreyszig, Advanced Engineering Mathematics 9th Edition, Wiley International Edition Press, Numerical Recipes for scientific computing.
2. Bhaskar Dasgupta, Applied Mathematical Methods, Pearson.
3. Arfken, Weber and Harris, Mathematical Methods for Physicists, A comprehensive guide, 7th Edition, Elsevier, 2013.
4. S.S. Sastry, Introductory methods of numerical analysis, Fifth edition, PHI.
5. Numerical methods in Engineering with MATLAB, Jaan Kiusalaas
6. Singiresu S Rao, *Engineering Optimization Theory and Practice*,5/e, John Wiley&Sons 2020.
7. Edwin K P Chong, Stanislaw H Zak, *An introduction to Optimization*, 2e, Wiley India.
8. Optimization in Electrical Engineering, Mohammad Fathi, Hassan Bevrani, Springer

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

No	Topic	No. of Lectures
1	***Systems of Linear Algebraic Equations:***	**9 hrs**
1.1	Uniqueness of Solution, Ill conditioning and norms	1
1.2	Methods of Solution: Gaussian elimination – LU factorization – Matrix inversion	3
1.3	Gauss-Siedel iteration – least squares method	2
1.4	Eigenvalue problems - Power method for eigen values – Tridiagonalization and QR factorization	3
2	***Interpolation and Curve Fitting***	**8 hrs**
2.1	Lagrange's Method, Newton's Method, Cubic Spline; Least-Squares Fit	3
2.2	Weighting of Data - Weighted linear regression;	1
2.3	Roots of Equations: Newton–Raphson Method for systems of equations;	1
2.4	Numerical differentiation - finite difference and first central difference approximations;	2
2.5	Numerical integration - trapezoidal and Simpson's rule	1
3	***Solution to differential equations:***	**7 hrs**
3.1	Initial Value Problems - Taylor Series Method,	1
3.2	Euler Method	1
3.3	Runge–Kutta Methods-Second-Order and Fourth Order;	2
3.4	Stability and Stiffness.	1

3.5	*Two-Point Boundary Value Problems:* Shooting Method and finite difference method (Concept only) *Case Study:* Two-Point Boundary Value Problems - Shooting Method (Demo/Assignment only)	2
4	***Constrained non-linear Optimization***	**8 hrs**
4.1	Optimisation *problem, Formulation of optimisation problems and linear optimization - Review only.*	1
4.2	Constrained non-linear Optimization-	1
4.3	Method of Lagrange multiplier, Necessary and sufficient conditions-	2
4.4	Equality and inequality constraints, Kuhn Tucker conditions,	2
4.5	Quadratic programming.	2
5	***Numerical optimization methods***	**8 hrs**
5.1	Direct search methods	2
5.2	Random search-pattern search	2
5.3	Descent Methods-Steepest descent, conjugate gradient.	2
5.4	Powell's method, Fletcher- Reeves method	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222TEE005	Flight Dynamics and Control	Core 3	3	0	0	3

Preamble:

To give insight into the dynamics, performance, and control of aircrafts.

Course Outcomes:

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

CO 1	Calculate and Analyze aircraft static stability characteristics
CO 2	Analyze dynamic flight conditions of aircraft using the non-linear state equations
CO 3	Assess aircraft stability from the linearized equations of motion
CO 4	Compute and demonstrate understanding of aircraft lateral and longitudinal modes and effects
CO 5	Analyze the performance of aircraft during climbing, cruising, gliding, turning, take-off and landing
CO 6	Estimate the requirement and availability of thrust and power for steady and level flight

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	

1. 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: 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.

End Semester Examination: 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.

Model Question paper

No. of Pages: **B**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH & YEAR

Branch: **Electrical & Electronics Engineering**

Course Code & Name:

222TEE005 FLIGHT DYNAMICS AND CONTROL

Max. Marks: 60 Duration: 2.5 hours

PART A

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

1. A jet transport aircraft with a mass of 120,000 kg is cruising with a speed of 400 knots at sea level. If the drag force is 290,000 N and the aircraft angle of attack is 3 degrees, a) How much thrust the engine is producing?
   b) How much lift force the engine is producing?
2. Consider an airplane patterned after the Fairchild Republic A-10, a twin-jet attack aircraft. The airplane has the following characteristics: wing area = 47m², aspect ratio = 6.5, Oswald efficiency factor = 0.87, weight = 103,047N, and zero-lift drag coefficient = 0.032. Estimate the sea-level landing ground roll distance for this airplane. Assume that the airplane is landing at full gross weight. The maximum lift coefficient with flaps fully employed at touchdown is 2.8. After touchdown, assume zero lift.
3. For the airplane in question 2., the sea-level corner velocity is 250 mi/hr, and the maximum lift coefficient with no flap deflection is 1.2. Calculate the minimum turn radius and maximum tum rate at sea level.
4. An aircraft is flying at level flight; total flight duration is 50 Minutes. At t = 20 minutes, the aircraft motion is changed from its trim position and there is a small variation in pitch rate and angle of attack. Also the speed leads the pitch angle variation by 90°. Explain the reason for the change in motion of the flight.
5. Which longitudinal dynamic stability mode performs as two degrees of freedom i.e., in $\Delta\theta$ and α? Explain its significance in aircraft motion.

PART B

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

6. Describe the translational motion of an airplane through three dimensional space over the Earth.
7. Derive the condition required for an un-accelerated, level, propeller-driven aircraft such that the pilot has to fly the longest possible duration in air using the Breguet formula.
8. The runway length required will be longer at higher altitude regions. Deduce an expression for take-off performance to support the above proposition.
9. Illustrate the variation of load factor with velocity for a given airplane taking into account the constraints on both. Discuss various aspects of overall airplane performance considering structural limitations.
10. A jet plane with an absolute ceiling of 12000 m climbs to an altitude of 9000 m. The rate of climb at sea level is given as 21 m/s, assuming a linear variation of ROC with altitude during the whole manoeuvre, calculate the time to climb.
11. Discuss how a displacement autopilot controls the vertical movement of an aircraft.
12. List out the significance of the Stability Augmentation System in an aircraft.

Syllabus

Module I

Aircraft Performance: Equations of Motion, thrust required for level, un -accelerated flight- Thrust available and Maximum Velocity, Power required for level, un-accelerated flight- Power available and maximum velocity, Altitude effects on power required and available- Rate of climb – Significance of maximum velocity and rate of climb in aircraft design – Gliding flight- Absolute and Service Ceilings - numerical problems.

Module II

Time to climb- range and Endurance-Propeller driven and Jet airplanes – Take-off performance- landing performance- Turning flight and V-n diagram-wing loading -load factor - Aircraft Equations of Motion: Aircraft axis systems - Coordinate transformations - Force and Moment equations - numerical problems

Module III

Longitudinal and Lateral Directional equations of motion - Kinematic Equations - Aircraft Stability and Control: Static stability - stability derivatives - Longitudinal applied forces and moments - Longitudinal Static stability - Stability Conditions - Numerical problems.

Module IV

Lateral applied forces and moments - Lateral Directional Static Stability - Stability Conditions - Aircraft Dynamic Stability - Basic review - transformation of linearized equations of motion to laplace domain - Longitudinal equations of motion to laplace domain - Numerical problems

Module V

Modes of motion: short period-phugoid-spiral divergence-dutch roll- roll coupling - Aircraft transfer functions-control surface actuator - Longitudinal autopilots- displacement autopilot- pitch autopilot - block diagrams-root locus- acceleration control systems -lateral autopilots- - attitude control systems – stability augmentation.

Course Plan

No	Topic	No. of Lectures
1	Aircraft Performance	
1.1	Equations of Motion, Thrust required for level, un -accelerated flight- numerical problems.	1
1.2	Thrust available and Maximum Velocity, Power required for level, un-accelerated flight- numerical problems.	2
1.3	Power available and maximum velocity, Altitude effects on power required and available- numerical problems.	1

1.4	Rate of climb – Significance of maximum velocity and rate of climb in aircraft design – numerical problems.	2
1.5	Gliding flight- Absolute and Service Ceilings - numerical problems.	2
2		
2.1	Time to climb- range and endurance-Propeller driven and Jet airplanes – numerical problems.	2
2.2	Take-off performance- landing performance- numerical problems	2
2.3	Turning flight and V-n diagram-wing loading -load factor - Aircraft Equations of Motion: Aircraft axis systems - Coordinate transformations - Force and Moment equations - numerical problems	4
3		
3.1	Longitudinal and Lateral Directional equations of motion - Kinematic Equations	2
3.2	Aircraft Stability and Control: Static stability - stability derivatives	3
3.3	Longitudinal applied forces and moments - Longitudinal Static stability - Stability Conditions - Numerical problems	3
4		
4.1	Lateral applied forces and moments - Lateral Directional Static Stability - Stability Conditions - Numerical problems	4
4.2	Aircraft Dynamic Stability - Basic review - transformation of linearized equations of motion to laplace domain - Longitudinal equations of motion to laplace domain	4
5		

5.1	Modes of motion: short period-phugoid-spiral divergence-dutch roll-roll coupling.	4
5.2	Aircraft transfer functions-control surface actuator	1
5.3	Longitudinal autopilots- displacement autopilot- pitch autopilot - block diagrams-root locus- acceleration control systems -lateral autopilots- -attitude control systems – stability augmentation.	3

40

Reference Books

1. John D Anderson Jr, 'Introduction to Flight' McGraw Hill International, 5/e,2005
2. John D. Anderson Jr, 'Fundamentals of Aerodynamics', Me Graw Hill International, 4/e, 2007.
3. Thomas R. Yechout, 'Introduction to Aircraft Flight Mechanics', AIAA Education Series,2003.
4. A.C.Kermode, ''Mechanics of Flight', Pearson Education, 10/e, 2005.
5. John H. Blakelock, 'Automatic Control of Aircraft and Missiles' 2/e, Wiley- Inter Science Publication, John Wiley and Sons, Inc., 1991.
6. Bernard Etkin, 'Dynamics of flight Stability and Control', John Wiley and Sons Inc. 3/e, 1996.
7. Robert C. Nelson, 'Flight Stability and Automatic Control', WCB McGraw-Hill, 2/e, 1998.
8. Louis V. Schmidt, 'Introduction to Aircraft Flight Dynamics' AIAA Education Series, 1997

Program Elective 3

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE047	NONLINEAR DYNAMIC SYSTEMS AND CONTROL	ELECTIVE 3	3	0	0	3

Preamble:

This course is intended to give a fundamental understanding of Nonlinear Control Systems and to equip the students to pursue research and development in the field of nonlinear control design.

Course Outcomes:

After the completion of the course the student will be able

CO 1	To be able to develop mathematical models of physical systems, to find the equilibrium sets, classify their types and to comprehend nonlinear phenomena.
CO 2	To study the notion of Lipschitz continuity and its usefulness in establishing the existence and uniqueness of the solution of a differential equation.
CO 3	To understand the various notions of stability and to be able to apply Lyapunov based analysis in establishing them.
CO 4	To be able to analyze the nonlinear systems for their absolute stability.
CO 5	To design nonlinear control techniques using linearization and recursive design techniques.

The departments conducting the M.Tech programme shall define their own PSOs, if required, and assessment shall also be done for the same.

Mapping of course outcomes with program outcomes

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

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: 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: 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 M 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.

Model Question Paper PAGES: 2

QP CODE:C

Reg.No:______________ Name:___

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE

EXAMINATION MONTH & YEAR

Course Code**: 222EEE047**

Course Name: **NONLINEAR DYNAMIC SYSTEMS AND CONTROL**

Max. Marks: 60 **Duration: $2\frac{1}{2}$ Hours**

PART A

Answer all questions

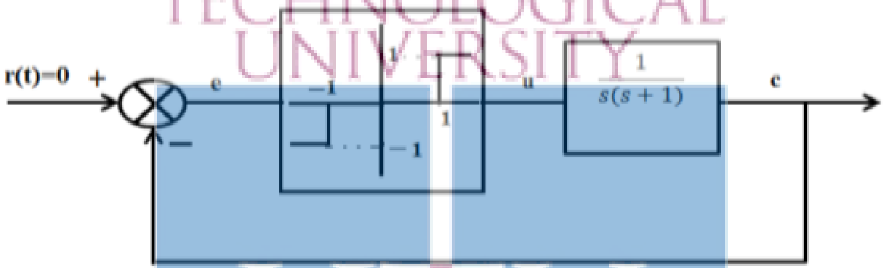
Each question carries 5 marks

1		What are singular points? Classify singular points based on Eigen values with necessary equations and phase trajectories.	5

2		State and prove the theorem on continuity of solutions in terms of initial states and parameters.	5
3		Check the stability of the following system using Lyapunov Stability analysis $\dot{x_1} = x_1(k^2 - {x_1}^2 - {x_2}^2) + x_2\,(k^2 + {x_1}^2 + {x_2}^2)$ $\dot{x_2} = -x_1(k^2 + {x_1}^2 + {x_2}^2) + x_2\,(k^2 - {x_1}^2 - {x_2}^2)$ When a) k=0 b) $k \neq 0$	5
4		Explain loop transformation applied to circle criterion.	5
5		Write notes on Integral control via linearization.	5

PART B

Answer any 5 full questions

6		For the system shown in Fig.1 with relay and dead zone as nonlinear element, draw the phase trajectory originating from the initial condition (3,0) using Isocline Method  Fig.1	7
7	a	Define Lipschitz function with suitable examples.	3
	b	Obtain the Lipschitz constant of the function $$f(x) = \begin{bmatrix} x_2 \\ -sat(x_1 + x_2) \end{bmatrix}$$	4
8		State LaSalle's invariance principle. Show that the origin is locally asymptotically stable for the following system using LaSalle's principle. $x_1' = x_2$ $x_2' = -3x_2 - x_1^3$	7

9		Find the sector [α, β] for which the given scalar transfer function is absolutely stable using Circle Criterion $$G(s) = \frac{s+2}{(s+1)^3}$$ $\dot{x}_1 = x_2 - x$ $\dot{x}_2 = - x_1 -$	7
10		Using backstepping, design a state feedback control law to globally stabilize the following system $$\dot{x}_1 = ax_1^2 - x_1^3 + x_2$$ $$\dot{x}_2 = u$$	7
11		Consider the system $$\dot{x}_1 = e^{x_2} - 1$$ $$\dot{x}_2 = ax_1^2 + u$$ Is this system feedback linearizable? If yes, find a feedback control law that linearizes the state equation.	7
12		Show that the following is input – state linearizable and obtain the co-ordinate transformation for the same. $$\dot{x}_1 = \exp(x_2)\,u$$ $$\dot{x}_2 = x_1 + x_2^2 + \exp(x_2)\,u$$ $$\dot{x}_3 = x_1 - x_2$$	7

Syllabus

Module I

Non-linear system characteristics and mathematical modelling of non-linear systems, Classification of equilibrium points, Linearization about equilibria of second order nonlinear systems, Bifurcations-different types, Phase plane analysis of nonlinear systems.

Module II

Closed orbits of planar dynamical systems, Open sets, closed sets, connected sets, Invariant set theorem, Bendixson's theorem and Poincare-Bendixson criteria, Existence and uniqueness of solutions to nonlinear differential equations with proof, Continuous dependence on initial conditions and parameters.

Module III

Lyapunov stability theorems- local stability - local linearization and stability in the small- region of attraction, The direct method of Lyapunov, Construction of Lyapunov functions, La Salles's invariance principle.

Module IV

Passivity, L stability and loop transformations, PR Lemma, KYP Lemma, Absolute stability, Circle Criterion, Popov criterion.

Module V

Basics of Differential Geometry-Controllability of nonlinear systems, Feedback linearization_Input state linearization method-Input-output linearization method, Zero Dynamics for SISO systems, Stabilization - regulation via integral control- gain scheduling, Backstepping.

Course Plan

No	Topic	No. of Lectures
1	**Introduction and background (7 hours)**	
1.1	Non-linear system characteristics and mathematical modelling of non-linear systems.	2
1.2	Classification of equilibrium points, Linearization about equilibria of second order nonlinear systems.	2

1.3	Bifurcations-different types, Phase plane analysis of nonlinear systems.	3
2	**Nonlinear characteristics (8 hours)**	
2.1	Closed orbits of planar dynamical systems	1
2.2	Open sets, closed sets, connected sets, Invariant set theorem, Bendixson's theorem and Poincare-Bendixson criteria	3
2.3	Existence and uniqueness of solutions to nonlinear differential equations with proof, Continuous dependence on initial conditions and parameters	4
3	**Stability Analysis (7 hours)**	
3.1	Lyapunov stability theorems- local stability - local linearization and stability in the small- region of attraction	2
3.2	The direct method of Lyapunov	2
3.3	Construction of Lyapunov functions, La Salles's invariance principle.	3
4	**Analysis of feedback systems (9 hours)**	
4.1	Passivity, L stability and loop transformations	3
4.2	PR Lemma, KYP Lemma, Absolute stability	2
4.3	Circle Criterion	2
4.4	Popov Criterion	2
5	**Nonlinear control systems design (9 hours)**	
5.1	Basics of Differential Geometry-Controllability of nonlinear systems	2
5.2	Feedback linearization_Input state linearization method-Input-output linearization method, Zero Dynamics for SISO systems	3
5.3	Stabilization - regulation via integral control- gain scheduling	2
5.4	Backstepping	2

Text Book:

1. Khalil H. K, Nonlinear Systems, 3/e, Pearson
2. Gibson J.E. Nonlinear Automatic Control, Mc Graw Hill.
3. Slotine J. E and Weiping Li, Applied Nonlinear Control, Prentice-Hall,

References:

1. Alberto Isidori, “Nonlinear Control Systems: An Introduction”, Springer-Verlag, 1985.
2. M. Vidyasagar, “Nonlinear Systems Analysis”, Prentice-Hall, India, 1991.
3. Shankar Sastry, “Nonlinear System Analysis, Stability and Control”, Springer, 1999.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE029	DEEP LEARNING	ELECTIVE3	3	0	0	3

Preamble:

This course will introduce the theoretical foundations, algorithms, methodologies, and applications of neural networks and deep learning. It will help to design and develop an application-specific deep learning models and also provide the practical knowledge handling and analysing real world applications.

Course Outcomes:

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

CO 1	A student at the end of course should be able to Decide if DL is suitable for a given problem
CO 2	Have a good understanding of the fundamental issues and basics of machine learning
CO 3	Choose appropriate DL algorithm to solve the problem with appropriate hyper parameter
CO 4	Setting Feel comfortable to read and understand DL articles from reputed conferences, journals including NIPS, CVPR, ICCV, ICML, PAMI etc.
CO 5	Outline the concept of the feed forward neural network and its training process
CO 6	Build CNN and Recurrent Neural Network (RNN) models for different use cases

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				
CO 2	1		1				
CO 3	2		3				
CO 4	3		2				

CO 5	2		3				
CO 6	3		3				

(1- Weak, 2-Medium, 3- strong)

Assessment Pattern

Bloom's Category	**End Semester Examination (%)**
Remember	25
understand	20
Apply	15
Analyse	

Mark distribution

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

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: 60 marks

The end semester examination will be conducted by the respective College. Therewill be two parts; Part A and Part B. Part A will contain 5 numerical/short answerquestions 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 (suchquestions shall be useful in the testing of overall achievement and maturity of thestudents in a course, through long answer questions relating totheoretical/practical knowledge, derivations, problem solving and quantitativeevaluation), with minimum one question from each module of which studentshould 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 astudent for each elective course shall be normalized accordingly. For example, if theaverage end semester mark % for a core course is 40, then the maximum eligiblemark % 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: 222EEE029

DEEP LEARNING

Max. Marks: 60 Duration: 2.5 hours

PART A

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

1. Discuss the different learning approaches used in machine learning
2. Explain the merits and demerits of using Auto encoders in Computer Vision.
3. What is the vanishing gradient problem and exploding gradient problem?
4. Give two benefits of using convolutional layers instead of fully connected ones for visual tasks.
5. Illustrate the workings of the RNN with an example of a single sequence defined on a vocabulary of four words

PART B

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

6. "A computer program is said to learn from experience E with respect to some class oftasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E." What is your understanding of the terms task, performance and experience. Explain with two example

7. Compare Boltzmann Machine with Deep Belief Network.
8. Write an algorithm for backpropagation which uses stochastic gradient descent method. Comment on the effect of adding momentum to the network.
9. Draw and explain the architecture of convolutional network ? Input to CNN architecture is a color image of size 112x112x3. The first convolution layer comprises of 64 kernels of size 5x5 applied with a stride of 2 and padding 0. What will be the number of parameters?
10. Explain the working of RNN and discuss how backpropagation through time is used in recurrent networks.
11. Derive update rules for parameters in the multi-layer neural network through the gradient descent.
12. What is the vanishing gradient problem and exploding gradient problem?

****

Syllabus

Module 1

Introduction - What is Deep Learning? – Machine Learning Vs. Deep Learning, representation Learning, Width Vs. Depth of Neural Networks, Activation Functions: RELU, LRELU, ERELU], Boltzmann Machines, Auto Encoders. Optimization Techniques, Gradient Descent, Batch Optimization, Back Propagation - Calculus of Back Propagation

Module 2

Bayesian Learning, Decision Surfaces Linear Classifiers, Machines with Hinge Loss, Unsupervised Training of Neural Networks, Restricted Boltzmann Machines, Auto Encoders. Perceptron and Multi-layer Perceptron – Hebbian Learning - Neural net as an Approximator, Training a neural network - Perceptron learning rule - Empirical Risk Minimization - Optimization by gradient descent

Module 3

Convergence in Neural networks - Rates of Convergence – Loss Surfaces – Learning rate and Data normalization, RMSProp, Adagrad and Momentum , Stochatic Gradient Descent, Acceleration – Overfitting and Regularization, Choosing a Divergence Loss Function – Dropout – Batch Normalization.

Module 4

Convolutional Neural Networks (CNN) - Weights as Templates – Translation Invariance , Training with shared parameters – Arriving at the convolutional model , Mathematical details of CNN, Alexnet – Inception – VGG - Transfer Learning

Module 5

Recurrent Neural Networks (RNNs), Modeling sequences - Back propagation through time - Bidirectional RNNs, Exploding/vanishing gradients - Long Short-Term Memory Units (LSTMs)

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Deep Learning (8)**	
1.1	Introduction - What is Deep Learning? – Machine Learning Vs. Deep Learning, representation Learning	1
1.2	Width Vs. Depth of Neural Networks, Activation Functions: RELU, LRELU, ERELU], Boltzmann Machines, Auto Encoders.	3
1.3	Optimization Techniques, Gradient Descent, Batch Optimization	2
1.4	Back Propagation - Calculus of Back Propagation,	2
2	**Neural Networks (8)**	
2.1	Bayesian Learning, Decision Surfaces Linear Classifiers, Machines with Hinge Loss	2
2.2	Unsupervised Training of Neural Networks, Restricted Boltzmann Machines, Auto Encoders	2
2.3	Perceptron and Multi-layer Perceptron – Hebbian Learning - Neural net as an Approximator	2
2.4	Training a neural network - Perceptron learning rule - Empirical Risk Minimization - Optimization by gradient descent	2
3	**Convergence in Neural networks (8)**	
3.1	Convergence in Neural networks - Rates of Convergence – Loss Surfaces – Learning rate and Data normalization	3
3.2	RMSProp, Adagrad and Momentum , Stochatic Gradient Descent	2
3.3	Acceleration – Overfitting and Regularization	1
3.4	Choosing a Divergence Loss Function – Dropout – Batch Normalization	2
4	**Convolution Neural Network (8)**	
4.1	Convolutional Neural Networks (CNN) - Weights as Templates – Translation Invariance	3
4.2	Training with shared parameters – Arriving at the convolutional model	2
4.3	Mathematical details of CNN	2
4.4	Alexnet – Inception – VGG - Transfer Learning	1
5	**Recurrent Neural Network (8)**	
5.1	Recurrent Neural Networks (RNNs)	2
5.2	Modeling sequences - Back propagation through time - Bidirectional RNNs	3
5.3	Exploding/vanishing gradients - Long Short-Term Memory Units (LSTMs)	3

Reference Books

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, Online book, 2017

2. Michael Nielsen, Neural Networks and Deep Learning, Online book, 2016

3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, " Deep Learning", MIT Press, 2017.
4. Josh Patterson, Adam Gibson "Deep Learning: A Practitioner's Approach", O'Reilly Media, 2017
5. Umberto Michelucci "Applied Deep Learning. A Case-based Approach to Understanding Deep Neural Networks" Apress, 2018.
6. Kevin P. Murphy "Machine Learning: A Probabilistic Perspective", The MIT Press, 2012.
7. Ethem Alpaydin,"Introduction to Machine Learning", MIT Press, Prentice Hall of India, Third Edition 2014.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE028	SLIDING MODE CONTROL	ELECTIVE3	3	0	0	3

Preamble:

To familiarize the students with the methodology for the design and implementation of sliding mode controllers for any uncertain plant and to design higher order sliding mode controllers and observers for real time systems.

Course Outcomes:

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

CO 1	Understand the theory of variable structure system
CO 2	Develop Sliding surface and sliding control for the given linear system
CO 3	Design robust nonlinear sliding mode controllers for any uncertain plant
CO 4	Design Discrete time Sliding Mode Control
CO 5	Develop higher order sliding mode 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	3		
CO 2	3			3	3		
CO 3	3			3	3		
CO 4	3			3	3		
CO 5	3	3		3	3		

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: 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: 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

QP CODE: **PAGES:2**

Reg.No:_______________

Name:_______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

MONTH & YEAR

Course Code: 222EEE028

Course Name: SLIDING MODE CONTROL

PART A

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

1. Write down the steps to be followed for designing a sliding mode controller. Also list the main features of sliding mode controllers. **(5)**

2. Design a stabilising variable structure control for a double integrator system **(5)**

3. Explain any one method of designing sliding surface for SMC **(5)**

4. Explain discrete time reaching laws associated with SMC **(5)**

5. Explain the concept of terminal sliding mode control **(5)**

PART B

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

6.Consider the system $\dot{x}$ = [0 1 ;4 5] x + [0 1] (u + d). Design a stable sliding surface s =[c ^T]x = 0 for the above system **(7)**

7. Explain various methods used to eliminate chattering in sliding mode control **(7)**

8. Consider the dynamical system $\dot{x}$ = [0 1; −2 3] x + [0 1] (u + d) y = [1 0]x. Discretize the system using zero order hold technique and then design discrete-time SMC for the system. Select τ = 0.1.? **(7)**

9. Explain how integral sliding mode can be designed for a second order chain of integrator system? **(7)**

10. Explain how discrete time sliding mode control can be designed using multirate output feedback **(7)**

11. Explain how sliding mode observer can be employed for a system with unmeasurable state variables? **(7)**

12. Distinguish between twisting algorithm and super twisting algorithms **(7)**

Syllabus

Module I

Introduction to variable structure systems, definition of variable structure and sliding mode, examples of dynamics system with sliding modes
Mathematical background: differential equations with discontinuous right hand sides, solutions in Filippov sense, existence conditions of sliding mode
Concept of a manifold, sliding surface, sliding mode motion and sliding mode control

Module II

Regular form approach-pole placement and LQR method, Properties of sliding mode motion, Reaching laws, method of equivalent control, Chattering problem, approaches of sliding hyper plane designs.

Module III

Discrete time sliding mode control, definition, design methods, Reaching laws of discrete time sliding mode control, Switching and non switching based discrete time sliding mode control

Module IV

Discrete time sliding mode control based on multi rate output feedback techniques. Terminal sliding mode, Integral sliding mode, Design of sliding surface and control law development

Module V

Sliding mode observers-Need of Sliding mode observers- Design of sliding mode observers, Design examples,Introduction to Higher order sliding mode control, twisting controller, super twisting controller

Course Plan

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Introduction to variable structure systems, definition of variable structure and sliding mode, examples of dynamics system with sliding modes. .	2
1.2	Mathematical background: differential equations with discontinuous right hand sides, solutions in Filippov sense, existence conditions of sliding mode	3
1.3	Concept of a manifold, sliding surface, sliding mode motion and sliding mode control	2
2	**Module II**	
2.1	Regular form approach-pole placement and LQR method,	4
2.2	Properties of sliding mode motion, Reaching laws, method of equivalent control,	2
2.3	Chattering problem, approaches of sliding hyper plane designs.	3
3	**Module III**	
3.1	Discrete time sliding mode control, definition, design methods,	2
3.2	Reaching laws of discrete time sliding mode control	2
3.3	Switching and non switching based discrete time sliding mode control	3
4	**Module IV**	
4.1	Discrete time sliding mode control based on multi rate output feedback techniques.	4
4.2	Terminal sliding mode, Integral sliding mode,	2
4.3	Design of sliding surface and control law development	3
5	**Module V**	
5.1	Sliding mode observers-Need of Sliding mode observers-	2
5.2	Design of sliding mode observers, Design examples	4

5.3	Introduction to Higher order sliding mode control , twisting controller, super twisting controller	2

40

Reference Books.

1. C. Edwards and S. K. Spurgeon, *Sliding mode control: Theory and applications*. Taylor and Francis; 1998.
2. V. I. Utkin, *Sliding Modes in Control Optimization*. New York: Springer-Verlag; 1992.
3. J. Y. Hung, W. Gao and J. C. Hung, *"Variable structure control: A survey;"* IEEE Transactions on Automatic Control; vol. 40; 1993.
4. Y. W. Weibing Gao and A. Homaifa, *"Discrete-time variable structure control systems*;" IEEE Transactions on Ind. Electronics; vol. 42; no. 2; pp. 117–122; 1995.
5. B. Bandyopadhyay and S. Janardhanan, *Discrete-time Sliding Mode Control*: A Multi-rate Output Feedback Approach,Springer-Verlag; 2005; no. 323.
6. K. Abidi, J. X. Xu, and Y. Xinghuo, "*On the discrete-time integral sliding-mode control*;" IEEE Transactions on Automatic Control; vol. 52; no. 4; pp. 709–715; 2007

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE049	**STOCHASTIC CONTROL**	**ELECTIVE 3**	**3**	**0**	**0**	**3**

Preamble:

This course is intended to apply the design algorithms to various physical systems with stochastic parameters. Provides a solid foundation on modelling and analysis of system with stochastic parameter.

Course Outcomes:

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

CO 1	Analyse the stability and performance of the systems with stochastic parameters
CO 2	Identify suitable estimation algorithm for stochastic systems.
CO 3	Formulate and design suitable control structure of stochastic system model.
CO 4	Implement optimal control algorithms to achieve specified performance for systems with stochastic parameters.

Mapping of course outcomes with program outcomes

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

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: 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: 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.

Model Question Paper

Pages **SLOT :C**

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

STREAM: Guidance and Navigation Control

222EEE049: Stochastic Control

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

	Part A **(Answer all questions)**	**Marks**
1	Consider the exponentially distributed random variable, X, that gives the time of failure for some system. The probability that X < T is determined by a probability density function $f(y) = \lambda e^{-\lambda y}$. Find the expected time of failure.	(5)
2	Let X be a uniform random variable that takes on values between 0 and 1. Let Y = lnX a) Give the probability density for function Y b) What is the probability that Y <3?	(5)
3	Consider the random telegraph wave. Are the sample functions differentiable with probability one? Is the process differentiable with probability one or in the mean square?	(5)
4	Consider the linear dynamical system $y(t) + ay(t-1) = e(t) + ce(t-1)$ Where y is the output and the input {e(t)} is sequence of independent normal (0,1) stochastic variables. Determine the covariance function of the output and the cross covariance of the input and output.	(5)
5	Define spectral factorization in stochastic control.	(5)
	Part B **(Answer any five questions)**	
6	Let = {1, 2, 3, 4} and consider A1 = {1, 2}, A2 = {3, 4}, B1 = {1, 3}, B2 = {2, 4}. Case 1: Define P ({1}) = P ({2}) = P ({3}) = P ({4}) = 1 4 so that P({A1}) = P({A2}) = P({B1}) = P({B2}) = 1 2. Show which of these events are independent and non-independent.	(7)

7	Let X and Y be independent random variables that are uniformly distributed on the interval [0,1]. Define Z(.) = X(.)Y(.) a) What is the mean, second moment and variance of Z? b) What is the probability that Z assumes a value less than 0.5? What about a value less than or equal to 0.5?	(7)
8	A dynamical system is governed by the stochastic difference equation $x(t+1) = \begin{pmatrix} 1.5 & 1 \\ -0.7 & 0 \end{pmatrix} x(t) + \begin{pmatrix} 1.0 \\ 0.5 \end{pmatrix} e(t)$ where {e(t), tϵT} is a sequence of independent normal, (0,σ), stochastic variables. Determine the covariance of the steady state distribution.	(7)
9	Evaluate the steady state covariance matrix for the state of the system $dx = \begin{bmatrix} -a_1 & -a_2 \\ 1 & 0 \end{bmatrix} x\,dt + \begin{bmatrix} 1 \\ 0 \end{bmatrix} dv$ Where a1>0, a2>0, {v(t), tϵT} is a Wiener Process with unit variance parameter.	(7)
10	Consider the stochastic differential equation $dx_1 = dw$ $dx_2 = x_1\,dw$ Where {w(t), tϵT} is a Wiener Process and all initial conditions are zero. The solution to the equation is $x_1(t) = w(t)$ $x_2(t) = \int_0^t w(s)\,dw(s)$ Calculate the mean value of x2.	(7)
11	Find the solution to the stochastic differential equation	(7)

	$$\begin{cases} dx_1 = x_2\,dt \\ dx_2 = dw \end{cases}$$ With initial condition x1(0) = 1, x2(0) = 0, where {w(t), tϵT} is a Wiener Process with unit variance parameter.	
12	The motion of a galvanometer in its thermal equilibrium with its surroundings is described by $$J\frac{d^2\varphi}{dt^2} + D\frac{d\varphi}{dt} + C\varphi = M$$ Where the torque M is due to collisions on the mirror by molecules of the air. Determine the variance and spectral density of the galvanometer's deflection if the torque M can be modelled with white noise.	(7)

Syllabus

Module 1

Introduction - Random Variables - Probability Distribution Function - Probability Density Function - Functions of Random Variables

Module 2

Expectations and Moments of Random Variables - Conditional Expectations and Conditional Probabilities - Correlation - Auto Correlation - Concept of Special Stochastic Processes - Covariance Function – Spectral Density.

Module 3

Stochastic State Models: Discrete Time Systems - Solution of Stochastic Difference Equations - Continuous Time Systems - solution - Linear Stochastic Differential Equations

Module 4

ITO Differentiation Rule - Modelling of Physical Process by Stochastic Differential Equations - Stochastic Integrals

Module 5

Analysis of Dynamical Systems with Stochastic Inputs: Discrete Time Systems - Spectral Factorization of Discrete Time Processes - Analysis of Continuous Time Systems with Stochastic Input - Spectral Factorization of Continuous Time Process -

Course Plan

No	Topic	No. of Lectures(40)
1		
1.1	Introduction	1
1,2	Random Variables	1
1.3	Probability Distribution Function	1
1.4	Probability Density Function	2
1.5	Functions of Random Variables	2
2		
2.1	Expectations and Moments of Random Variables	1
2.2	Conditional Expectations and Conditional Probabilities	1
2.3	Correlation	1
2,4	Auto Co-relation - Concept of Special Stochastic Processes	3
2.5	Covariance Function – Spectral Density.	2
3	Stochastic State Models:	
3.1	Discrete Time Systems - Solution of Stochastic Difference Equations	2
3.2	Continuous Time Systems - solution	3
3.3	Linear Stochastic Differential Equations	3
4		
4.1	ITO Differentiation Rule	2
4.2	Modelling of Physical Process by Stochastic Differential Equations.	3
4.3	Stochastic Integrals	3
5	Analysis of Dynamical Systems with Stochastic Inputs:	
5.1	Discrete Time Systems	2
5.2	Spectral Factorization of Discrete Time Processes	2

5.3	Analysis of Continuous Time Systems with Stochastic Input	2
5.4	Spectral Factorization of Continuous Time Process	2

Reference Books

1. Jason L. Speyer and Walter H. Chung, “Stochastic Process, Estimation and Control,” Siam Philadelphia, 2008.

2. Karl J. Åström, “Introduction to Stochastic Control Theory,” Academic Press, New York and London, 1970.

3. KaddourNajim, Enso Ikonen and Ait-Kadi Daoud, “Stochastic Processes Estimation, Optimization & Analysis,” Kogan Page Science, London and Sterling, 2004.

4. Birkhäuser, “Stochastic Switching Systems Analysis and Design,” Library of Congress Cataloguing-in-Publication Data, United States of America, 2006.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE050	Estimation Theory	ELECTIVE 3	3	0	0	3

Preamble:

To train the students to implement a state feedback controller by estimating the state of the system and should be able to apply the estimation algorithms to estimate unknown quantities from the available measured signals.

Course Outcomes:

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

CO 1	Apply basics of probability theory in estimation and differentiate different types of noises
CO 2	Apply the estimation algorithms to estimate unknown quantities from the available measured signals
CO 3	Implement optimal estimation algorithms to estimate signals from noisy data for linear as well as nonlinear systems
CO 4	Appreciate that the method of maximum likelihood estimation is an important way of estimating a parameter.
CO 5	Analyze the estimation problems and apply suitable estimation algorithms

Mapping of course outcomes with program outcomes

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

No. of Pages: **C**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH & YEAR

Branch: **Electrical & Electronics Engineering**

Course Code & Name:

222EEE050 ESTIMATION THEORY

Max. Marks: 60 Duration: 2.5 hours

PART A

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

1. Find the mean and variance of a random variable that is uniformly distributed between 1 and 3. The PDF of the RV is given as

$$f_X(x) = \begin{cases} 1/2 & x \in [1,3] \\ 0 & otherwise \end{cases}$$

2. The altitude of a free falling object is given by $r = r_0 + v_0 t + (a/2)t^2$. r is measured at various time instants and fit a quadratic to the resulting r versus t curve, the quadratic data fitting problem can be written as $y_k = x_1 + x_2 t_k + x_3 t_k^2 + v_k$, $E(v_k^2) = R_k$, t_k is the independent variable and y_k is the noisy measurement. Develop a recursive least square estimator to estimate the constants x1, x2 and x3.
3. Show the propagation of state covariance of a continuous time system with time using Sylvester's equation.
4. In an airplane system winds are buffeting the plane and there are anemometers to measure wind speed as an input to the Kalman Filter. So the random gusts of wind affect both the process (i.e., the airplane dynamics) and the measurement (i.e., the sensed wind speed). What modifications can be brought out in standard Kalman Filter to deal with the situation?
5. Differentiate between fixed lag and fixed interval smoothing.

PART B

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

6. Justify that an auto covariance matrix is symmetric and positive definite.
7. Justify the importance of error covariance matrix in recursive least square estimation.
8. Compare Least Square and Weighted least Square Estimation.
9. A system has the transfer function G(s) = 1 / (s-3). If the input is an impulse, there are two solutions for the output x(t) that satisfy the transfer function. One solution is causal and unstable, the other solution is anti-causal and stable. Find the two solutions.
10. Consider a linear system, in which angular acceleration of the motor is controlled by the applied voltage across motor windings. the simplified motor model is given as:

$$\dot{\theta} = \omega$$

$$\dot{\omega} = u + w_1$$

w1 is the acceleration noise which includes uncertainty in the applied acceleration, motor shaft eccentricity and load disturbances. The measurement consists of angular position of the motor with a scalar measurement noise. Discretize the system to find the single step state transition matrix Fk and the discrete-time input matrix Gk.

11. Compare the formulation and performance between iterated EKF and Second order EKF.
12. Write down the steps required to include non-linear measurements in the estimation problem using second order EKF.

Syllabus

Module I

Elements of Probability and Random Process: Sample Spaces and Events - Axioms of Probability - Conditional Probability – Continuous Probability - Probability Functions - Bayes' Formula-Random Variables – Expectation - Variance - Covariance - White and Colored Noises - Correlated Noise – Numerical problems

Module II

Least Square Estimation: Estimation of Constant, Weighted Least Square Estimation, Recursive Least Square Estimation – Wiener filtering - Propagation of States and Co-Variance - Continuous Time and Discrete Time Systems – Kalman Filter: Discrete-time Kalman Filter- Properties-Propagation of Covariance – Numerical problems and Simulations

Module III

Sequential Kalman Filtering - Information Filtering – Square root Filtering – Correlated Process and Measurement Noise - Colored Process and Measurement Noise – Steady State Filtering – Numerical problems and Simulations

Module IV

Continuous Time Kalman Filter: Discrete time and Continuous time White Noise Solution through Riccati Equation – Generalization of Continuous -time Filter – Steady State Filter – Numerical problems and Simulations

Module V

Optimal Smoothing: Fixed-point Smoothing- Fixed-lag Smoothing – Fixed-interval Smoothing – Nonlinear Kalman Filter: Linearized Kalman Filter – Extended Kalman Filter – Numerical problems and Simulations - Higher Order Approaches – Parameter Estimation.

Course Plan

No	Topic	No. of Lectures
1	Elements of Probability and Random Process:	
1.1	Sample Spaces and Events - Axioms of Probability - Conditional Probability – Numerical problems	2
1.2	Continuous Probability - Probability Functions - Bayes' Formula-Random Variables – Numerical problems	3
1.3	Expectation - Variance - Covariance - White and Colored Noises - Correlated Noise – Numerical problems	3
2	Least Square Estimation:	
2.1	Estimation of Constant, Weighted Least Square Estimation, Recursive Least Square Estimation – Numerical problems and Simulations	2

2.2	Wiener filtering - Propagation of States and Co-Variance - Continuous Time and Discrete Time Systems – Numerical problems and Simulations	3
2.3	Kalman Filter: Discrete-time Kalman Filter- Properties- Propagation of Covariance – Numerical problems and Simulations	3
3		
3.1	Sequential Kalman Filtering - Information Filtering – Square root Filtering – Numerical problems and Simulations	2
3.2	Correlated Process and Measurement Noise - Colored Process and Measurement Noise – Numerical problems and Simulations	3
3.3	Steady State Filtering – Numerical problems and Simulations	3
4	Continuous Time Kalman Filter:	
4.1	Discrete time and Continuous time White Noise	2
4.2	Solution through Riccati Equation – Numerical problems and Simulations	3
4.3	Generalization of Continuous -time Filter – Steady State Filter – Numerical problems and Simulations	3
5		
5.1	Optimal Smoothing: Fixed-point Smoothing- Fixed-lag Smoothing – Fixed-interval Smoothing – Numerical problems and Simulations	3
5.2	Nonlinear Kalman Filter: Linearized Kalman Filter – Extended Kalman Filter – Numerical problems and Simulations	3
5.3	Higher Order Approaches – Parameter Estimation.	2

Reference Books

1. Dan Simon, "Optimal State Estimation Kalman, H infinity and Nonlinear Approaches," Wiley Inter-science, John Wiley & Sons, Inc., Publication, 2006.

2. R. G> Brown, P. Y. C. Hwang, "Introduction to Random Signals and Applied Kalman Filtering with Matlab Exercises", 4th Edition, Wiley Publishers, 2012.

3. Athanasios Papoulis and S. Unnikrishna Pillai, "Probability, Random Variables and Stochastic Process," Tata McGraw-Hill Publishing Company Limited, New Delhi, India, 2002.

4. Sheldon M. Ross, "Introduction to Probability and Statistics for Engineers and Scientists," 3/e, Academic Press, Delhi, India, 2005.

5. Jerry M. Mendel, "Lessons in Estimation Theory for Signal Processing, Communications and Control," Prentice Hall PTR, Englewood Cliffs, New Jersey, USA, 1995.

6. Paul Zarchan and Howard Musof, "Fundamentals of Kalman Filtering: A Practical Approach," AIAA Inc. Alexander Bell Drive, Reston, Vergenia, 2000.

7. Robert Grover Brown and Patrick Y. C. Hwang, "Introduction to Random Signals and Applied Kalman Filtering," 3/e, John Wiley & Sons, Inc., Publication, Canada, 1997.

8. Alexander D. Poularikas and Zayed M. Ramadan, “Adaptive Filtering Primer with MATLAB,” CRC Press, Taylor & Francis, Boca Raton, London, 2006.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE051	ADAPTIVE CONTROL	ELECTIVE 3	3	0	0	3

Preamble:

This course is intended to give a fundamental understanding of Adaptive Control Systems and to equip the students to pursue research and development in the field of Adaptive control design.

Course Outcomes:

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

CO 1	Provide knowledge on various adaptive schemes, with a basic understanding on closed loop system stability and implementation issues
CO 2	Develop ability to design suitable stable adaptive scheme to meet the performance objectives even in the presence of disturbances and changing operating conditions
CO 3	Design model reference adaptive control system considering matched structured uncertainties
CO 4	Analyze the stability of Direct and Indirect –time algorithms
CO 5	Identify the need and apply appropriate adaptive control design technique to real-time 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	3						
CO 3	3						
CO 4	3						
CO 5	3						
CO 6	3						

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: 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: 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.

Model Question Paper

PAGES: 2

QP CODE:

Reg.No:______

Name:_

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION MONTH & YEAR

Course Code:**222EEE051**

Course Name: **Adaptive Control**

Max. Marks: 60	Duration: $2\frac{1}{2}$ Hours

PART A

Answer all questions
Each question carries 5 marks

1		Explain the recursive least square estimation (RLS) algorithm used in adaptive control systems	5
2		Explain MDPP algorithm used in the design of self tuning regulators.	5
3		Define MIT rule for MRAS scheme.	5
4		With a suitable block diagram explain gain scheduling method.	5
5		Briefly explain about controller design issues.	5

PART B

Answer any 5 questions out of 7

6		Explain the different types of adaptive schemes with the help of block diagram.	7
7		Explain the algorithm for the design of indirect self tuning regulator.	
8		Design a model following minimum degree pole placement controller for a continuous time process $G(s) = \frac{1}{s(s+1)}$. The sampling period is 0.5sec. The desired closed loop system has natural frequency of 1 rad /sec and relative damping of 0.7.	7
9	a	How stability is ensured in MRAS systems using Lyapunov theory?	4
	b	What is the significance of adaptation gain in MRAC systems?	3
10		With suitable example explain the procedure to design a gain scheduling controller with nonlinear transformation.	7
11		What are the operational difficulties in the implementation of adaptive control scheme	7

		and how they are handled?	
12		Explain the term controller windup and how it is handled in a system.	7

SYLLABUS

Module I

Introduction to Adaptive Control, adaptive Schemes and adaptive Control problem, Real-Time Parameter Estimation: Regression Models - Recursive Least Squares Estimation and Exponential Forgetting, Estimating Parameters in Dynamical Systems - FIR models-Experimental Conditions.

Module II

Pole Placement Design, MDPP – Estimation and Design of Indirect Self-tuning Regulators, Continuous Time Self-tuners –NMP systems - Direct Self-tuning Regulators -Properties of Direct Self-tuners, Disturbances with Known Characteristics, Case Study.

Module III

MIT Rule - Determination of Adaptation Gain, Lyapunov Stability Theory - Design of MRAS using Lyapunov Theory, Adaptation of a Feed forward Gain - Applications–Design of Stable Adjustment Mechanisms, Case Study.

Module IV

Nonlinear Dynamics and Analysis – Adaptation of a feed forward gain, Stability analysis of Direct and Indirect –time algorithms, Averaging Techniques – Robust Adaptive Controllers, Design of Gain Scheduling controllers and a few applications.

Module V

Controller implementation issues – Controller Design issues, Estimation implementations,

Industrial Adaptive Controllers, Chemical Reactor Control, Autopilot Design.

Course Plan

No	Topic	No. of Lectures
1	**Introduction and background (7 hours)**	
1.1	Introduction on Adaptive Control, adaptive Schemes and adaptive Control problem - A few applications.	2

1.2	Real-Time Parameter Estimation: Regression Models - Recursive Least Squares Estimation and Exponential Forgetting.	3
1.3	Estimating Parameters in Dynamical Systems - FIR models- Experimental Conditions.	2
2	**Deterministic Self-Tuning Regulators (8 hours)**	
2.1	Pole Placement Design, MDPP – Estimation and Design of Indirect Self-tuning Regulators.	3
2.2	Continuous Time Self-tuners –NMP systems - Direct Self-tuning Regulators - Properties of Direct Self-tuners.	4
2.3	Disturbances with Known Characteristics, Case Study.	1
3	**Model Reference Adaptive Systems(8 hours)**	
3.1	MIT Rule - Determination of Adaptation Gain.	2
3.2	Lyapunov Stability Theory - Design of MRAS using Lyapunov Theory.	2
3.3	Adaptation of a Feed forward Gain - Applications–Design of Stable Adjustment Mechanisms, Case Study	4
4	**Properties(9 hours)**	
4.1	Nonlinear Dynamics and Analysis – Adaptation of a feed forward gain.	2
4.2	Stability analysis of Direct and Indirect –time algorithms.	2
4.3	Averaging Techniques – Robust Adaptive Controllers.	2
4.4	Design of Gain Scheduling controllers and a few applications.	3
5	**Practical Issues, Implementation and Application:(8 hours)**	
5.1	Controller implementation issues – Controller Design issues.	1
5.2	Estimation implementations.	3
5.3	Industrial Adaptive Controllers.	2
5.4	Chemical Reactor Control – Autopilot Design.	2

Text Book:

1.Karl Johan Astrom and BjomWittenmark, 'Adaptive Control' , Addison Wesley,2003.

References:

1. Karl Johan Astrom and BjomWittenmark, 'Adaptive Control' , Addison Wesley,2003.
2. Shankar Sastry, 'Adaptive Control', PHI (Eastern Economy Edition), 1989
3. Karl Johan Astrom, 'Adaptive Control', Pearson Education, 2001.
4. Petros A Loannou, Jing, 'Robust Adaptive Control', Prentice-Hall, 1995.
5. Eykhoff P, 'System Identification: Parameter and State Estimation', 1974.
6. Miroslav Kristic, Ioannis Kanellakopoulos and PetarKokotovic,
7. "Nonlinear and Adaptive Control Design," John Wiley and Sons, 1995.

Program Elective 4

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE052	Guidance and Control of Missiles	ELECTIVE 4	3	0	0	3

Preamble:

This course covers the basics of missiles, guidance laws for missiles and its applications to tactical missiles with the integrated flight control system.

Course Outcomes:

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

CO 1	Analyze interception and avoidance of aerospace vehicles with appropriate guidance law
CO 2	Choose suitable guidance law based on different missile target engagement scenario
CO 3	Analyze modern guidance of missile target engagement for maneuvering and non-maneuvering targets qualitatively
CO 4	Compare guidance laws based on time, miss-distance, launch vehicle boundaries, control effort and implementation
CO 5	Design flight control system for typical missile-target engagement scenario

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	3	1	3
CO 2	3	1	2	2	2	2	2
CO 3	3	2	3	3	3	3	2
CO 4	1	1	3	1	2	2	3
CO 5	3	2	2	2	3	3	3

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: 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: 60 marks

There will be two parts; Part A and Part B. Part A contain 5 numerical questions /short answer 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

No. of Pages: **D**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH & YEAR

Branch: **Electrical & Electronics Engineering**

Course Code & Name:

222EEE052 GUIDANCE AND CONTROL OF MISSILES

Max. Marks: 60 Duration: 2.5 hours

PART A

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

1. Consider a surface to air missile-target engagement scenario with point mass, and moving with constant velocities and constant heading angles. Plot the engagement trajectory in (V_R, V_θ) space and specify the conditions required for collision course, target evasion and zero miss distance.

2. For an air-to-air attack engagement scenario, initially the pursuer pursues the target but finally the target evades from the pursuer's field-of-view. Justify the situation on the basis of turn radius and specify the implemented guidance law.

3. For the intercept geometry shown in Fig.1, with the given initial conditions, find the final LOS at which the missile approaches the target.

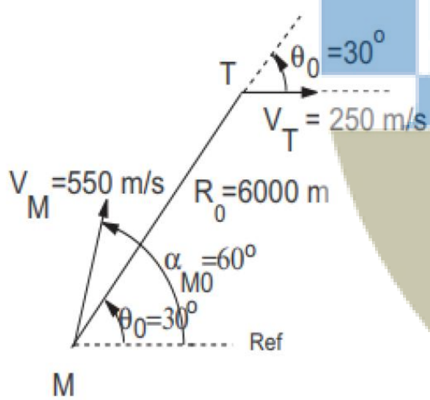


Figure 1.

4. Show the Augmented Proportional Navigation Guidance law with an effective navigation ratio of 3 is the same as the optimal guidance law in linearized kinematics.

5. Justify the effect of process and measurement noise covariances in matrix Riccatti equation.

PART B

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

6. Define capturability. Give the conditions for capturability in a missile - target engagement scenario.
7. Differentiate between CLOS and Beam Rider Guidance laws.
8. Choose a Lyapunov function and derive optimal guidance law for commanded acceleration. Hence prove the optimality of proportional navigation guidance law.
9. Describe the signi_cance of dither signal in self adaptive autopilot system.
10. Compare the significance of compensation gain in commanded acceleration profile using Beamrider guidance and CLOS guidance.
11. With the help of necessary equations, summarize the generation of control commands by three-loop-autopilot system in missiles.

12. In a Missile Target engagement problem, the missile acceleration, latax is the control variable perpendicular to the Missile velocity vector. The engagement geometry is as shown in Fig.2. Develop an optimal control problem i.e., TBVP, with specified state variable functions at defined final time.

(a) Write the Hamiltonian for the specified problem.
(b) Write the co-state functions
(c) Write Boundary Conditions
(d) Develop Optimization function

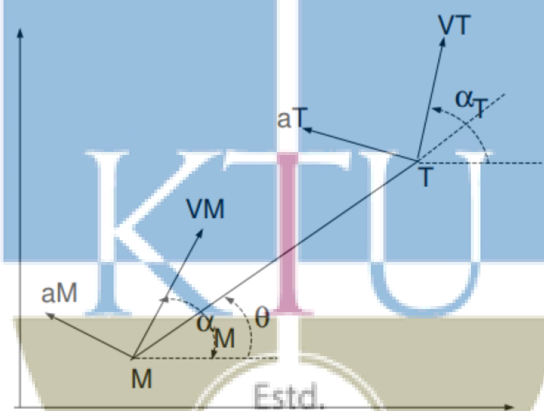


Figure 2:

Syllabus

Module I

History of Guided Missile for Air Defence Applications - Classification of Missiles - Tactical Missile Description-Fundamentals of Guidance - Basic Results in Interception and Avoidance.

Module II

Taxonomy of Guidance Laws, Command and Homing Guidance - Classical Guidance Laws - Pursuit, LOS, CLOS, BR - Numerical problems - Proportional Navigation – Linearized Engagement Simulation - PNG Variants Like PPN, BPN, APN, TPN, GPN and IPN.

Module III

Augmented Proportional Navigation Guidance - Modern Guidance Laws-Guidance Laws Derived from Optimal Control Theory and Lyapunov method - PPN with Non-Manoeuvring Targets– Qualitative analysis - Lambert Guidance: Solution to Lambert Problem – Booster steering – General Energy Management Steering – Numerical Problems - Strategic Intercepts - Ballistic Engagement Simulation – Gravity compensation – Predictive Guidance – Pulsed Guidance

Module IV

Missile Autopilots - Flight Control System-Pitch, Yaw and Roll Autopilot - Control Surfaces Autopilot Commands - Dither Adaptive Control-lnertial Reference Adaptive Control - Functional Block Diagram-Angle Tracking and Seeker Head Stabilization-Radom Refraction Aerodynamics for Autopilot Design-Missile Control Methods.

Module V

Optimal Filtering- Simulations. Formulation of optimal control for performance of aerospace systems-Riccatti Equations-Performance measure - Optimal mid-course guidance – Design and Simulate Optimal guidance problem for homing, impact angle control, impact time control, and impact time and angle control.

Course Plan

No	Topic	No. of Lectures
1		
1.1	History of Guided Missile for Air Defence Applications - Classification of Missiles	1
1.2	Tactical Missile Description-Fundamentals of Guidance	2
1.3	Basic Results in Interception and Avoidance	2
2		
2.1	Taxonomy of Guidance Laws, Command and Homing Guidance	1
2.2	Classical Guidance Laws - Pursuit, LOS,CLOS, BR - Numerical problems	3
2.3	Proportional Navigation – Linearized Engagement Simulation - PNG Variants Like PPN, BPN, APN, TPN, GPN and IPN.	3
2.4	Special topics: tactical vs. strategic considerations in guidance, impact of noise on guidance, target maneuver and evasion	3
3		
3.1	Augmented Proportional Navigation Guidance - Modern guidance Laws-Guidance Laws Derived from Optimal Control Theory and Lyapunov method - PPN with Non-Manoeuvring Targets–Qualitative analysis	3
3.2	Lambert Guidance: Solution to Lambert Problem – Booster steering – General Energy Management Steering – Numerical Problems	3
3.3	Strategic Intercepts - Ballistic Engagement Simulation – Gravity compensation – Predictive Guidance – Pulsed Guidance	3
4		
4.1	Missile Autopilots - Flight Control System-Pitch, Yaw and Roll Autopilot - Control Surfaces Autopilot Commands - Dither Adaptive Control-lnertial Reference Adaptive Control	4
4.2	Functional Block Diagram-Angle Tracking and Seeker Head Stabilization-Radom Refraction Aerodynamics for Autopilot Design-Missile Control Methods.	4
5		

5.1	Optimal Filtering- Simulations. Formulation of optimal control for performance of aerospace systems-Riccatti equations-Performance measure	4
5.2	Optimal mid-course guidance – Design and Simulate Optimal guidance problem for homing, impact angle control, impact time control, and impact time and angle control.	4

40

Reference Books

1. George M. Siouris, 'Missile Guidance and Control Systems', Springer Verlag, New York Inc., 2004.

2. Paul Zarchan, 'Tactical and Strategic Missile Guidance', AIAA, Inc., Sixth Edition, 2012.

3. N.A. Shneydor, 'Missile Guidance and Pursuit: Kinematics, Dynamics and Control', Ellis Horwood Publishers, 1998.

4. Eichblatt E. J., 'Test and Evaluation of the Tactical Missiles', AIAA Inc, 1989

5. Ching-Fang-Lin, 'Modern Navigation, Guidance and Control Processing', Prentice- Hall, Inc., Englewood Cliffs, New Jersey, 1991

6. R. Yanushevsky, 'Modern Missile Guidance', CRC Press, 2008.

7. P. Garnell, 'Guided Weapon Control Systems', Second Edition, Brassey'sDefence Publishers, London, l987.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE053	ROBUST CONTROL	ELECTIVE4	3	0	0	3

Preamble: Nill

Course Outcomes:

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

CO 1	Model the given uncertain system in structured or unstructured form.
CO 2	Model the given system using state space and LFT formulation.
CO 3	Analyse the robustness of the control system using Robust Stability and Robust Performance measures.
CO 4	Validate and design a controller using Kharitonov approaches.
CO 5	Explain the concepts of mu controllers and LMI
CO 6	Perform the case studies of a few standard uncertain systems in stability aspects

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	
Analyse	
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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: 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.

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

2nd Semester M. Tech in EEE

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

222EEE053 ROBUST CONTROL

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

PART A

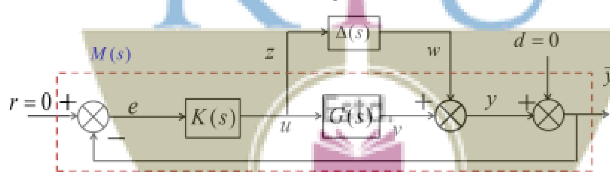
Answer ALL questions. Each question carries 5 marks.

Questions	CO	KL
1. What are the different configurations of unstructured uncertainty in a control system?	1	1
2. What are the design aspects to be taken care of in the design of SISO feedback systems a) to improve disturbance rejection? b) to improve robustness?	2	2

3.	Discuss the significance of co-prime factorization of the plant and the controller	3	1
4.	What are the limiting factors to the application of Kharitonov Theorem? State the Bounded Phase Lemma	4	2
5.	Give basic control aspects behind Linear Matrix Inequality (LMI)	5	2

PART B

Answer ANY 5 questions. Each question carries 7 marks.

	Questions	CO	KL
1.	For the system shown in the figure below, derive the condition for robust stability 	2	3
2.	List the algorithm steps for suboptimal H-infinity control problem formulation	3	2
3.	Define Boundary Crossing Theorem? Describe how stability test of a family of interval polynomials can be done?	4	3
4.	State the Segment Lemma: Hurwitz case. Validate the robustness of the following affine interval plant with suitable theorem $\frac{A}{B} = \frac{-0.66s^2 - [102.5, 192]s + [386.3, 717.6]}{s^4 + 5.2s^3 + [24.9, 40.6]s^2 + [2.7, 4.3]s + [2,3.9]}$	4	3
5.	Discuss the modeling of Inverted Pendulum Control System and write the MATLAB codes for its controller design	5	7
6.	Derive the linear fractional transformation formulation from the generalized plant and and finally to the M-Delta structure with sutable diagrams. Write its equivalent state space matrix structure	2	3
7.	How to select the weights in H-infinity control problem? What are the conditions for the suitability of h-infinity controller? Explain the factors which affect weights selection in h-infinity control	2	2

Syllabus and Course Plan

No	Topic	No. of Lectures

1	*Modelling of parametric Uncertain systems*	
1.1	Definition and classification of robust control-Elements of robust control theory – Classification of uncertainties- Parametric (structured), neglected and lumped (unstructured) - Additive and multiplicative	3
1.2	Sensitivity and Complementary Sensitivity function and its peak selection - Its relation to gain and phase margin -Relation between Sensitivity and disturbance inputs in a feedback system - Weighted Sensitivity and weighted complementary sensitivity.	3
1.3	Single degree of freedom design structure for SISO systems for disturbance and noise rejection	2
2	H-inf *Loop shaping and Weight Selection*	
2.1	H-inf control optimization techniques-state space formulation control problem and solution – Selection of weighting functions – Parameter selection rules in the weighting function - general Control algorithm	3
2.2	Concept of loop shaping - System modelling with parameter uncertainty-general concepts	2
2.3	M-delta configuration- Linear Fractional Transformation (LFT) formulation-examples - Singular value decomposition.	3
3	*Robust Stability and Robust Performance*	
3.1	Well-posedness - internal stability - Co-prime factorization of plant and controller	2
3.2	Nominal Performance- Nominal Stability - Robust Performance - Robust Stability - Small gain theorem	3
3.3	Boundary crossing theorem - Bounded Real Lemma - Schur stability test - Hurwitz stability test	3
4	*Robust Kharitonov Validation*	
4.1	Robust stability validation using parametric approach- Kharitonov approach for stability – Kharitonov theorem –16 plant theorem	3
4.2	Controller design using Kharitonov theorem	2
4.3	Interval Polynomial Families-Segment Lemma-Affine Interval Plants with single and multiple variables-Edge Theorem	3
5	*Case Studies and LMI Concept*	
5.1	Basic concepts of H2 and μ – synthesis controllers – Applying H2 and H-inf Control for some applications	3
5.2	Case studies using MATLAB – Inverted Pendulum Control System Design	3
5.3	LMI basics – Control problems using LMI	2

Reference Books

1. 1. Kemin Zhou, "Essentials of Robust Control," Prentice-Hall, 1998
2. S P Bhattacharya, L H Keel and H Chapellat "Robust Control: The Parametric Approach," Prentice-Hall, 1995
3. Da-Wei Gu, Petko H. Petkov and Mihail M. Konstantinov, "Robust Control Design with MATLAB," 2nd Edition, Springer, 2013
4. Kang-Zhi Liu and Yu Yao, "Robust Control – Theory and Applications," Wiley, 2016

CODE	Course Name	CATEGORY	L	T	P	CREDIT
222EEE054	SYSTEM IDENTIFICATION	ELECTIVE 4	3	0	0	3

Preamble:

To design suitable performance measure to meet the specification requirements and to analyse the physical system, design the structure of system model by optimizing the suitable performance criteria by satisfying the constraints over the system parameter, apply the design algorithms to various physical systems with unknown system parameters and to provide a solid foundation on modelling of system with stochastic parameter.

Course Outcomes:

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

CO 1	Describe the different phases that constitute the process of building models, from identification experiment to model validation
CO 2	Describe and motivate basic properties of identification methods like the least squares method, the prediction error method, the instrumental variable method, as well as to solve simple problems that illustrate these properties
CO 3	Describe the principles behind recursive identification and its fields of application
CO 4	Formulate and design suitable structure of system model

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2	1	3	2	1	1	1
CO 2	2	1	3	3	2	2	2
CO 3	3		3	3	3	1	2
CO 4	3	1	2	3	3	2	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: 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: 60 marks

There will be two parts; Part A and Part B. Part A contain 5 numerical questions /short 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

No. of Pages: **D**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH & YEAR

Branch: **Electrical & Electronics Engineering**

Course Code & Name:

222EEE054 SYSTEM IDENTIFICATION

Max. Marks: 60 Duration: 2.5 hours

PART A

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

1. Consider the linear regression model

$y(t) = a + bt + \varepsilon_1(t)$

Estimate the parameter b using linear regressions.

2. Consider a stationary stochastic process y(t) with spectral density

$\Phi_y(\omega) = (1/2\pi)\ (5-4\cos\omega)/(8.2 - 8\cos\omega)$

Show that this process can be represented as a first-order ARMA process.

3. Consider the proces given by y(t) = e(t) + 2e(t-1)

Where e(t) is white noise of zero mean and unit variance. Derive the optimal mean square one-step predictor and find the variance of the prediction error.

4. Give the significance of the forgetting factor in the recursive least square algorithm.

5. Write the steps involved in the model validation and structure determination process.

PART B

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

6. Consider the linear regression model

$y(t) = a + bt + \varepsilon(t)$

Find the least square estimates of a and b.

7. Consider the state space model

$$x(t+1) = \begin{pmatrix} a_{11} & a_{12} \\ a_{12} & a_{22} \end{pmatrix} x(t) + \begin{pmatrix} b \\ 0 \end{pmatrix} u(t)$$

$$\theta = (a_{11} \quad a_{12} \quad a_{22} \quad b)^T$$

Examine the uniqueness properties for the following cases:

a) The first state variable is measured

b) The second state variable is measured

c) Both the state variables are measured

8. Develop prediction for the ARMAX model

y(t) + a y(t-1) = b u(t-1) + e(t) + c e(t-1)

where e(t) is zero means white noise of variance λ^2. Assume that u(t) and e(s) are independent for t<s.

9. Compare basic and extended instrument variable methods.

10. Estimate recursively the constant in the model y(t) = b+ e(t), where e(t) denotes disturbance of λ^2.

11. Identify the parameters using pseudo linear regression method for the ARMAX model

$$A(q^{-1})y(t) = B(q^{-1})u(t) + C(q^{-1})e(t)$$

12. Give the significance of Consistency analysis in model validation and structure determination process.

Syllabus

Module I

Introduction – nonparametric and parametric methods – Bias- consistency and model approximation - Nonparametric methods: - Transient analysis-frequency analysis – Correlation and Spectral analysis - Linear regression - Least square estimate – analysis - Numerical problems.

Module II

Input Signals – Spectral Characteristics – Persistent Excitation – Spectral properties of periodic signals - Model classification – model structure – uniqueness property – identifiability – spectral factorization - Numerical problems.

Module III

Prediction Error methods – Optimal prediction – Theoretical analysis and computational aspects – Instrumental variable methods – theoretical analysis - Numerical problems and Simulations

Module IV

Recursive identification methods: Recursive least square – real-time identification – recursive instrumental variable – recursive prediction error – practical overview - Identification of Systems operating in Closed `loop – identifiability condition – direct identification – joint input output identification - Analysis – Numerical problems and Simulations

Module V

Model validation and model structure determination – Analysis test on covariance function - Practical Aspects: Design of the experimental condition – determination of model structure – time delays - initial conditions – robustness – model verification – software aspects – Numerical problems and Simulations.

Course Plan

No	Topic	No. of Lectures
1		
1.1	Introduction – nonparametric and parametric methods – Bias-consistency and model approximation	3
1.2	Nonparametric methods: - Transient analysis-frequency analysis – Correlation and Spectral analysis	3

1.3	Linear regression - Least square estimate – analysis – numerical problems	4
2		
2.1	Input Signals – Spectral Characteristics – Persistent Excitation – Spectral properties of periodic signals	3
2.2	Model classification – model structure – uniqueness property – identifiability – spectral factorization	4
3		
3.1	Prediction Error methods – Optimal prediction – Theoretical analysis and computational aspects	4
3.2	Instrumental variable methods – theoretical analysis	4
4		
4.1	Recursive identification methods: Recursive least square – real-time identification – recursive instrumental variable – recursive prediction error – practical overview	5
4.2	Identification of Systems operating in Closed `loop – identifiability condition – direct identification – joint input output identification - Analysis	4
5		
5.1	Model validation and model structure determination – Analysis test on covariance function	3
5.2	Practical Aspects : Design of the experimental condition – determination of model structure – time delays - initial conditions – robustness – model verification – software aspects	3

40

Reference Books

1. Torsten Soderstrom, Petre Stoica, “System Identification”, Prentice Hall International Series in Systems and Control Engineering, 2001.
2. Karel J. Keesman, “System Identification: An Introduction”, Springer, 2011
3. Lennart Ljung, System Identification Theory for the User, Prentice Hall Information Systems Science Series, 1987.
4. Sinha N. K., Kuztsas, ‘System Identification and Modeling of Systems’, 1983.
5. Harold W. Sorensen, 'Parameter Estimation’, Marcel Dekker Inc, New York, 1980.
6. Daniel Graupe, Identification of Systems,Van Nostrand.
7. Tohru Katayama, ‘Subspace Methods for System Identification’, Springer-Verlag London Limited, 2005.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE055	**MULTIAGENT SYSTEMS**	**ELECTIVE 4**	**3**	**0**	**0**	**3**

Preamble:

To give a foundation to design controllers for multiagent systems to achieve consensus, formation etc.

Course Outcomes:

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

CO 1	To understand the matrix theory basics required for the analysis of multiagent systems.
CO 2	To understand the graph theory basics required for the analysis of multiagent systems.
CO 3	To analyse the agreement/consensus protocol and design a state feedback protocol for continuous time multi-agent systems.
CO 4	To design the consensus protocol for a discrete time case and also to design observer based protocol
CO 5	To analyse and design the formation control in multi-agent systems

Mapping of course outcomes with program outcomes

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

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: 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: 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.

Model Question Paper

Pages **SLOT D**

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

STREAM:

222EEE055: Multiagent systems

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

	Part A **(Answer all questions)**	**Marks**
1	Check whether matrix A=[1 2 0 0 3 4 5 6 7] is reducible or irreducible	(5)
2	Prove that if G is a directed graph with n vertices and k connected components(weakly connected) then rank of incidence matrix is $n-k$.	(5)
3	A digraph, D on n vertices contains a rooted out-branching as a subgraph if and only if rank(L(D)) =n−1 and in that case, N(L(D)) is spanned by the vector of all ones.	(5)
4	For an identical N multi-agent system described by $d/dt(x_i)=Ax_i+Bu_i$ $y_i=Cx_i$ where i=1,2,..N suggest and explain a full-order observer based consensus protocol.	(5)
5	Illustrate what is a scale invariant formation with the help of an example.	(5)
	Part B **(Answer any five questions)**	
6	Prove that for every unit eigenvalues of a stochastic matrix is semi-simple.	(7)

7	Prove that for a weakly connected graph, G with n vertices, rank of incidence matrix is $n-1$.	(7)
8	Prove that for a connected undirected graph, the agreement protocol $\dot{x}(t) = -L(G)x(t)$ converges to the agree… $\Re^n$, is the subspace span{1}) with a rate of convergence decided by λ_2, where the spectrum of laplacian for a connected undirected graph is $\lambda_n > \lambda_{n-a} \ldots \lambda_2 > \lambda_1 = 0$.	(7)
9	Suppose the communication graph of an N multi-agent systems described by $x_i(k+1) = Ax_i(k) + Bu_i$ $y_i(k) = Cx_i(k)$ where $i=1,2,..N$ contains a directed spanning tree and they will reach the consensus under the protocol $u_i = K \sum_{j=1}^{N} d_{ij}(x_i - x_j)$ if and only if the matrices $A+(1-\lambda_i)BK$, $i=1,..,N$ are Schur stable and λ_i are the eigenvalues of the row stochastic matrix D, located in the open unit disk. The entries of matrix D are denoted by d_{ij}	(7)
10	Let D_j be a directed spanning tree relative state specification and D_d be an arbitrary relative state specification. Then show that the following relationship hold $T_{dj} = D(D_j)^T D(D_j)[D(D_j)^T D(D_j)]^{-1}$ where $D(D_j)$ and $D(D_d)$ represents the incidence matrix associated with D_j and D_d and T_{dj} the linear transformation satisfying $T_{dj} D(D_j)^T = D(D_d)^T$	(7)
11	Prove that for a complete graph K_n with n vertices eigenvalues of Adjacency matrix are $n-1$ with multiplicity 1 and -1 with multiplicity $n-1$.	(7)

12	A digraph, D on n vertices contains a rooted out-branching as a subgraph if and only if rank(L(D)) =n−1 and in that case, N(L(D)) is spanned by the vector of all ones.	(7)

Syllabus and Course Plan

Syllabus

Module 1

Introduction and Matrix Theory:

Introduction to multi-agent systems- examples, Eigen values, Left and right eigenvectors, Jordan normal form- algebraic and geometric multiplicity-simple and semisimple eigenvalue, semi-convergence and convergence of discrete-time linear systems, spectrum and spectral radius, stochastic matrices-M-matrices-properties- Irreducible and Primitive matrices-Perron-Frobenius theorem-Kronecker product and properties

Module 2

Graph Theory:

Graphs -directed and undirected-underlying graph-vertices-edges-path indegree-outdegree-neighbours-balanced graph, regular graph,self loop, path graph-ring graph- complete- bipartite graph,subgraph-induced subgraph- various operations on subgraphs- connectedness,cyclic-acyclic-trees and spanning tree-connectivity properties of digraph- weighted graph

Incidence matrix-Adjacency matrix,Diagonal -in-degree matrix- Laplacian matrix- properties-signed path vector

Module 3

Consensus protocol:

Agreement protocol in undirected and directed networks: agreement subspace, convergence rate to the agreement space, rooted out-branching. State feedback consensus protocol design for continuous discrete time systems.

Module 4

Consensus protocol for discrete time case and observer type consensus protocol :

State feedback consensus protocol design for discrete time systems. Observer based consensus protocol for continuous and discrete time systems

Module 5

Formation control of multiagent systems:

Formation control-shapes-types-rigid and flexible framework--rigidity-, infinitesimal and minimal rigidity and rigidity matrix- relative state specification; Shape-based control; Relative state-based control.Extension of consensus protocol to formation control.

Course Plan

No	Topic	No. of Lectures(40)
1		
1.1	Introduction to multi-agent systems- examples	1
1,2	Eigen values, Left and right eigenvectors, Jordan normal form-algebraic and geometric multiplicity-simple and semisimple eigenvalue,	1
1.3	semi-convergence and convergence of discrete-time linear systems, spectrum and spectral radius	1
1.4	stochastic matrices- Irreducible and Primitive matrices- M-matrices-properties	2
1.5	Perron-Frobenius theorem--Kronecker product and properties	2
2		
2.1	Graphs -directed and undirected-underlying graph-vertices-edges-path indegree-outdegree-neighbours-balanced graph, regular graph,self loop, path	1
2.2	complete- bipartite graph,subgraph-induced subgraph- various operations on subgraphs	1
2.3	connectedness,cyclic-acyclic-trees and spanning tree-connectivity properties of digraph- weighted graph	1
2,4	Incidence matrix-Adjacency matrix,Diagonal -in-degree matrix-properties	3
2.5	Laplacian matrix- properties-signed path vector	2
3		
3.1	Agreement protocol in undirected networks: agreement subspace, convergence rate to the agreement space	2
3.2	Agreement protocol in directed network rooted out-branching.	3
3.3	State feedback consensus protocol design for continuous time systems	3

4		
4.1	State feedback consensus protocol design for discrete time systems	2
4.2	Observer based consensus protocol for continuous time system	3
4.3	Observer based consensus protocol for discrete time system	3
5		
5.1	Formation control- shapes-types-rigid and flexible framework	2
5.2	rigidity-, infinitesimal and minimal rigidity and rigidity matrix-relative state specification	2
5.3	Shape-based control	2
5.4	Relative state-based control	2

Reference Books

1. M. Mesbahi and M. Egerstedt, “Graph Theoretic Methods in Multiagent Networks”, Princeton University Press, NJ, 2010.

2. F.Bullo, “Lectures on Network Systems”,Kindle Direct Publishing,Edition 1.6, 2022.

3. W. Ren and R.W. Beard, “Distributed Consensus in Multi-vehicle Cooperative Control: Theory and Application”, Springer-Verlag, London, 2008.

4. F. Lewis, H. Zhang, K. Hengster-Movric and A. Das, “Cooperative Control of Multi-Agent Systems: Optimal and Adaptive Design Approaches”, Springer-verlag, London, 2014.

5. R. B. Bapat, “Graphs and Matrices”, Hindustan Book Agency, Springer-Verlag, London, 2011.

6. Carl D Meyer, Matrix Analysis and Applied Linear Algebra, SIAM, 2001.

7. Z. Li, Z. Duan, G. Chen and L. Huang, “Consensus of Multi-agent Systems and Synchronization of Complex Networks: A Unified Viewpoint”, IEEE Transactions on Circuits and Systems-I: Regular Papers, Vol. 57-1, 2010.

8. H. Zhang, F. L. Lewis and A. Das, “Optimal Design for Synchronization of Cooperative Systems: State Feedback, Observer and Output Feedback”, IEEE Transactions on Automatic Control, vol. 56, no. 8, 2011.

9. Z. Li and Z. Duan, “Cooperative control of multi-agent systems: A consensus region approach”, CRC Press Taylor and Francis Group.

CODE	COURSE CODE	CATEGORY	L	T	P	CREDIT
222EEE048	**Helicopter Dynamics**	**ELECTIVE 4**	**3**	**0**	**0**	**3**

Preamble:

To give insight into the principle of operation and control of Helicopters

Course Outcomes:

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

CO 1	Apply the basic concepts of helicopter dynamics
CO 2	Comprehend the interrelationships that exist between the aerodynamics, flight mechanics, stability and control when applied to helicopters
CO 3	Examine flying qualities of helicopters in hover and forward flight
CO 4	Perform blade element analysis, investigate rotating blade motion, and quantify basic helicopter 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	2	3	3	2	1	2
CO 2	2	1	3	3	1	1	2
CO 3	2	2	2	3	2	1	1
CO 4	2	1	1	2	1		1

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: 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: 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.

Model Question paper

No. of Pages: **D**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH & YEAR

Branch: **Electrical & Electronics Engineering**

Course Code & Name:

222EEE048 HELICOPTER DYNAMICS

Max. Marks: 60 Duration: 2.5 hours

PART A

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

1. Summarize the necessity of swash plate and anti-torque pedals in synchropter with suitable figure.

2. A helicopter with a gross weight of 3000 lb, a main rotor radius of 13.2 ft, and a rotor tip speed of 680 ft/s has 275 hp delivered to the main rotor shaft. For hovering conditions at sea level: Compute (a) the rotor disk loading, (b) the ideal power loading, (c) the thrust and torque coefficients, and (d) the figure of merit and actual power loading.

3. Show that for a hovering rotor with blades that operate at constant lift and drag coefficients, the thrust on the rotor is proportional to the square of the tip speed, and the power is proportional to the cube of the tip speed.

4. The simple momentum theory assumes that the jump in pressure across the disk of a hovering rotor is the same everywhere. By considering an elemental annulus of the rotor disk, prove that this is consistent with a distribution of lift across the rotor disk that varies linearly from zero at the rotational axis of the rotor.

5. Compare static dynamic stability in-view of helicopter motion.

PART B

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

6. Most modern helicopters are of the single main rotor and tail rotor(conventional) type configuration. For the same overall aircraft gross weight, what might be the relative advantages of a tandem rotor helicopter over a conventional helicopter? Also compare the potential relative merits of a coaxial rotor over a tandem design.

7. Find the effective drag coefficient, C_D, acting on a rotor that is in vertical autorotation at $V_c / \nu_h = -1.85$.

8. Explain the effect of lateral oscillation of a helicopter following an angular displacement in hovering.

9. Relate blade pitch angle with mean blade pitch. In helicopter rotors high amounts of twist over the blade span is non optimum for the entire flight envelope. Justify it.

10. Discuss about response degradation in helicopter flight envelope limits.

11. Explain the combined effect of Angle of Attack and offset of thrust from centre of gravity of helicopter.

12. (a) The induced velocity at the rotor plane in hover is known to be a function of rotor tip speed, the rotor thrust, the rotor disk area and air density. By means of dimensional analysis, show that the functional form of induced velocity, $\lambda_i = f(C_T)$.

(b) Calculate and plot the values of slip stream in fully contracted wake of hovering rotor at sea as a function of disk loading, T/A. Assuming a figure of merit of 0.75, compute and plot power loading vs disk loading.

Syllabus

Module I

Introduction - History of Helicopter Flight - Rotor Aerodynamics Configuration – articulated rotor system – cyclic pitch change- Momentum Theory: Thrust generation – Hovering - Figure of Merit - Blade Element Theory - local solidity – tip loss- Performance in hovering and climbing: optimum hovering rotor – induced torque – profile drag torque – performance equation – ground effect

Module II

Flow states of the rotor: vortex ring – wind mill – vertical descent performance – autorotation - Performance in horizontal flight: flapping – steady hover – blade hinge motion – Induced velocity – blade element angle of attack – torque coefficient – drag force – numerical problems

Module III

Forward flight: performance equation – drag lift ratio – induced drag – profile power – parasite power – Blade stall – power loss – means for delaying blade stall – calculation of angle of attack at retreating tip – losses – numerical problems

Module IV

Stability and Control: Trim – static stability – dynamic stability - Helicopter trim analysis: Sample trim problem – procedures – results - Rotor static stability – stability in hover – dynamic stability – stability reduction - Flying Qualities in Hover: Equations of motion – Vertical Dynamics – Yaw Dynamics - Longitudinal Dynamics – Lateral Dynamics – Coupled Longitudinal and Lateral Dynamics

Module V

Flying Qualities in Forward Flight: Equations of motion - Longitudinal Dynamics - Lateral Dynamics – Tandem Helicopters – Low frequency rotor response - Stability Augmentation - Flying Quality Specifications.

Course Plan

No	Topic	No. of Lectures
1		
1.1	Introduction - History of Helicopter Flight - Rotor Aerodynamics Configuration – articulated rotor system – cyclic pitch change	2
1.2	Momentum Theory: Thrust generation – Hovering - Figure of Merit	2
1.3	Blade Element Theory - local solidity – tip loss	2
1.4	Performance in hovering and climbing: optimum hovering rotor – induced torque – profile drag torque – performance equation – ground effect	2
2		

2.1	Flow states of the rotor: vortex ring – wind mill – vertical descent performance - autorotation	2
2.2	Performance in horizontal flight : flapping – steady hover – blade hinge motion – numerical problems	2
2.3	Induced velocity – blade element angle of attack – torque coefficient – drag force – numerical problems	3
3		
3.1	Forward flight: performance equation – drag lift ratio – induced drag – profile power – parasite power – numerical problems	4
3.2	Blade stall – power loss – means for delaying blade stall – calculation of angle of attack at retreating tip – losses – numerical problems	4
4		
4.1	Stability and Control : Trim – static stability – dynamic stability	1
4.2	Helicopter trim analysis : Sample trim problem – procedures - results	2
4.3	Rotor static stability – stability in hover – dynamic stability – stability reduction	2
4.4	Flying Qualities in Hover: Equations of motion – Vertical Dynamics – Yaw Dynamics	2
4.5	Longitudinal Dynamics – Lateral Dynamics – Coupled Longitudinal and Lateral Dynamics	2
5		
5.1	Flying Qualities in Forward Flight: Equations of motion - Longitudinal Dynamics	3
5.2	Lateral Dynamics – Tandem Helicopters – Low frequency rotor response	3
5.3	Stability Augmentation - Flying Quality Specifications	2
		40

Reference Books

1. Wayne Johnson, 'Helicopter Theory', Dover Publications Inc., New York, Second Edition, 1994.

2. G. D. Padfield, Helicopter Flight Dynamics: The Theory and Application of Flying Qualities and Simulation Modelling, Blackwell Publishing, 2nd Edition, 2007.

3. E. Rathakrishnan, 'Helicopter Aerodynamics', PHI Learning PVT Lmtd, 2018.

4. C. Venkatesan, 'Fundamentals of Helicopter Dynamics', CRC Press Taylor and Francis, 2017.

5. J. Gordon Leishman, 'Principles of Helicopter Aerodynamics', Cambridge University Press, Second Edition. 2006.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE057	MECHATRONICS AND ROBOTICS	ELECTIVE 4	3	0	0	3

Preamble:

To Familiarise mechatronic system design for robots and various methods of control schemes for robots.

Course Outcomes:

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

CO 1	Familiarise with mechatronic system models and design.
CO 2	Analyse different control schemes for mechatronic systems
CO 3	Obtain the kinematic model of a robotic manipulator and to plan trajectories for a robot
CO 4	Familiarize with robot control architecture and dynamics
CO 5	Develop dynamic model of rigid bodies and control of elastic system modelling

Mapping of course outcomes with program outcomes

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

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: 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: 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.

Model Question paper

Course Code & Name:

222EEE057 MECHATRONICS AND ROBOTICS

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	Describe why the analogies are important in modelling of dynamic systems? In the force-current analogy, what mechanical element corresponds to an electrical capacitor?	(5)
2	Briefly explain the testing and instrumentation methods of mechatronic product or system	(5)
3	A single-link robot with a rotary joint is motionless at $\theta\theta$ = 15 degrees. It is desired to move the joint in a smooth manner to $\theta\theta$ = 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)
4	Write a short note on space station robotics	(5)

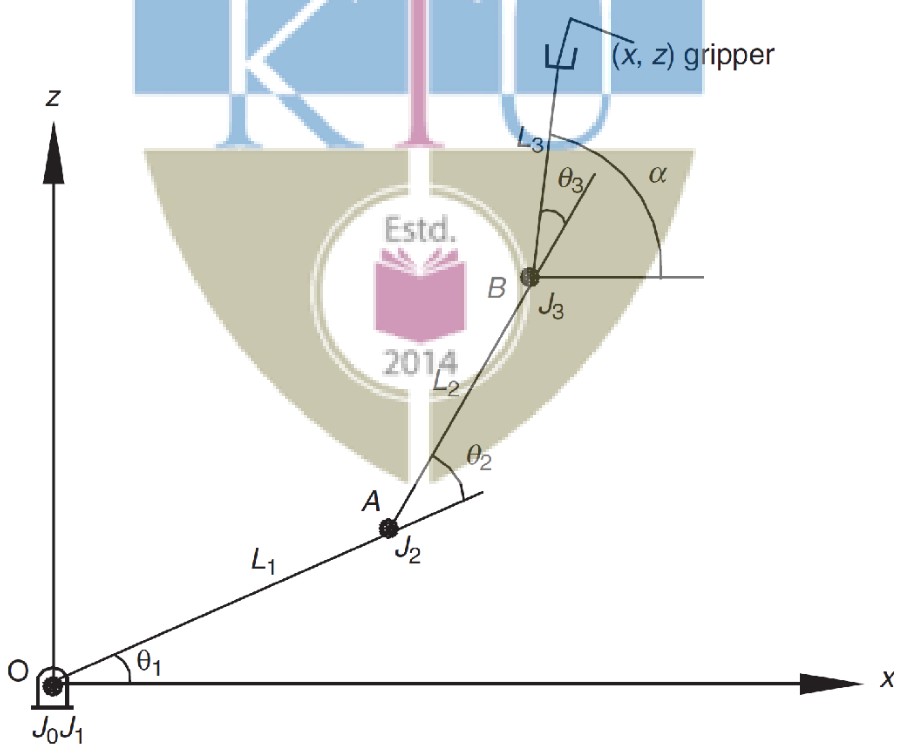
5 Write and explain Lagrange’s Equations of Motion for Electromechanical Systems. (5)

PART B

6 You are assigned with the task of designing and instrumenting a mechatronic system. With the help of a suitable block diagram explain the procedure in detail. (7)

7 Explain in detail about the Microprocessor Control and Microprocessor Numerical control. (7)

8 The links of a 3R robotic arm are L1= 350 mm, L2= 250mm and L3= 50 mm. The gripper is at world coordinates given as x=300 mm, Z= 400mm and α = 30_. Determine the angles θ1, θ2 and θ3, which the motor controlling the shoulder, elbow, and wrist have to be rotated. (7)



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

b. Write a short note on the basic building block of a robotic manipulator. (4)

10 With a suitable block diagram, explain Robot Control Architecture in detail (7)

11 a. List and explain different robotic sensors (5)

b. Describe the essential features of robotic gripper with application. (2)

12	Explain the importance of elastic system modelling in formulating the dynamics of a metallic link manipulator.	(7)

Syllabus

Module I

Introduction to mechatronics: Basic Definitions, Mechatronic Systems - Modelling and Design, Mechatronic Design Concept, Evolution of Mechatronics - Dynamic Models and Analogies- Terminology, Model Types, System Response, Model Development - Mechanical Elements, Electrical Elements, Thermal Elements, Fluid Elements

Module II

System interfacing and Instrumentation - Introduction, Input Signals of a Mechatronic System, Output Signals of a Mechatronic System, Signal Conditioning - Microprocessor Control, Microprocessor Numerical Control, Software Control - Testing and Instrumentation

Module III

Robotic systems - Types of robots, Robotic arm terminology, Robotic arm configuration, Robot applications - Robotic manipulator kinematics - Robotic arm positioning concepts, Robotic arm path planning - Actuators

Module IV

Robot Dynamics - Space-Station Robotics, Robot Control Architecture - Friction and Backlash, Robotic Sensors - Robotic Grippers, Gripper Features, Analytical Model

Module V

Modelling Electromechanical System - Models for Electromechanical Systems, Rigid Body Models - Basic Equations of Dynamics of Rigid Bodies- Simple Dynamic Models - Elastic System Modelling, Electromagnetic Forces- Dynamic Principles for Electric and Magnetic Circuits

Course Plan

No	Topic	No. of Lectures
1	Introduction to mechatronics	
1.1	Basic Definitions, Mechatronic Systems	1
1.2	Modelling and Design, Mechatronic Design Concept, Evolution of Mechatronics	3
1.3	Dynamic Models and Analogies- Terminology, Model Types, System Response, Model Development	3
1.4	Mechanical Elements, Electrical Elements, Thermal Elements, Fluid Elements	2

2	System interfacing and Instrumentation	
2.1	Introduction, Input Signals of a Mechatronic System, Output Signals of a Mechatronic System, Signal Conditioning	3
2.2	Microprocessor Control, Microprocessor Numerical Control, Software Control	3
2.3	Testing and Instrumentation	1
3	Robotic systems	
3.1	Types of robots, Robotic arm terminology, Robotic arm configuration, Robot applications	2
3.2	Robotic manipulator kinematics	3
3.3	Robotic arm positioning concepts, Robotic arm path planning	2
	Actuators	1
4	Robot Dynamics	
4.1	Space-Station Robotics, Robot Control Architecture	2
4.2	Friction and Backlash, Robotic Sensors	2
4.3	Robotic Grippers, Gripper Features, Analytical Model	3
5	Modelling Electromechanical System	
5.1	Models for Electromechanical Systems, Rigid Body Models	2
5.2	Basic Equations of Dynamics of Rigid Bodies- Simple Dynamic Models	3
5.3	Elastic System Modelling, Electromagnetic Forces- Dynamic Principles for Electric and Magnetic Circuits	3

Reference Books

1. Godfrey Onwubolu - Mechatronics_ Principles and Applications-Butterworth-Heinemann (2005)

2. Robert H. Bishop - Mechatronics. An Introduction-CRC Press (2005)

3. de Silva W. - Mechatronics-CRC Press Inc (2004)

4. Zoran Gacovski (Editor) - Mechatronics and Robotics-Arcler Press (2020)

5. Miomir Vukobratović Ph. D., D. Sc. (auth.) - Introduction to Robotics-Springer-Verlag Berlin Heidelberg (1989)

6. (Open University Press Robotics Series) D. McCloy, D. M. J. Harris (auth.) - Robotics_ An Introduction-Springer Netherlands (1986)

Industry / Interdisciplinary Elective

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE070	**Energy Efficiency in Electrical Engineering**	**INTERDISCIPLINARY ELECTIVE**	**3**	**0**	**0**	**3**

Preamble: The course aims to understand various forms & elements of energy and evaluate the techno economic feasibility of the energy conservation technique adopted.

Course Outcomes:

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

CO 1	Understand the various forms & elements of energy.
CO 2	Assess energy efficiency in Electrical Supply System and Motors
CO 3	Analyse energy Efficiency in Electrical Utilities .
CO 4	Identify methods of energy conservation in Lighting , DG systems and transformers
CO 5	Evaluate energy efficient technologies in Electrical Systems

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				1	
CO 2	2		2		1		
CO 3	2		2	1			
CO 4	2		2		1		
CO 5	2		2		1		

Assessment Pattern

Bloom's Category	End Semester Examination (marks in percentage)
Apply	30
Analyse	40
Evaluate	30
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 exam 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

QP CODE:
PAGES: 2

Reg No:_______________

Name:_________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222EEE070

Course name: Energy Efficiency in Electrical Engineering

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

PART-A (Answer All Questions. Each question carries 5 marks)

1) State the meaning and need of Energy Conservation.

2) List any four factors to be considered while selecting motor for any particular application.

3) Explain the concept of Energy Efficiency Ratio (EER)

4) Compare conventional core transformer with amorphous core transformer on the basis of i) Construction ii) Material used iii) Losses and iv) Cost

5) State any four benefits of Variable Frequency Drives (VFDs).

PART-B (Answer any 5 Questions. Each question carries 7 marks)

6) Explain the impact of energy usage on climate.

7) State three advantages of improvement of Power Factor at Load side.

Power Factor at the load side is 0.75 and average minimum load is 100 kW. What is the kVAr rating of capacitor to improve the Power Factor at the load side to 0.95 ?

8) A 50 kw induction motor with 86% full load efficiency is being considered for replacement by a 89% efficiency motor. What will be the saving in energy if motor works for 6000 hrs. per year and cost of energy is Rs. 4.50 per kwh?

9) What are the factors affecting the performance and savings opportunities in HVAC

10) What are the energy efficiency opportunities in DG systems?

11) What is energy efficient motors? Explain with technical aspects.

12) Explain different energy efficient lighting control with features.

Syllabus

Module 1: Energy Scenario:

Classification of energy, Capacity factor of solar and wind power generators, Global fuel reserve, Energy scenario in India, Impact of energy usage on climate, Salient features of Energy Conservation Act 2001 & The Energy Conservation (Amendment) Act, 2010 and its importance. Prominent organizations at centre and state level responsible for its implementation, Standards and Labelling.

Module 2: Energy Efficiency in Electrical Supply System and Motors

Electrical system: Electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit, selection and location of capacitors, performance assessment of PF capacitors, distribution and transformer losses.
Electric motors: Types, losses in induction motors, motor efficiency, factors affecting motor performance, rewinding and motor replacement issues, energy saving opportunities with energy efficient motors.

Module 3: Energy Efficiency in Electrical Utilities

Pumps: Introduction to pump and its applications, Efficient pumping system operation, Energy efficiency in agriculture pumps, Tips for energy saving in pumps
Compressed Air System: Types of air compressor and its applications, Leakage test, Energy saving opportunities in compressors.
HVAC and Refrigeration System: Introduction, Concept of Energy Efficiency Ratio (EER), Energy saving opportunities in Heating, Ventilation and Air Conditioning (HVAC) and Refrigeration Systems
Fans and blowers: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities.

Module 4 : Energy Efficiency in Lighting , DG systems and transformers

Lighting Systems: Basic definitions- Lux, lumen and efficacy, Types of different lamps and their features, Energy efficient practices in lighting
DG Systems: Introduction, Energy efficiency opportunities in DG systems, Loading estimation
Transformers: Introduction, Losses in transformer, transformer Loading, Tips for energy savings in transformers

Module 5 :Energy Efficient Technologies in Electrical Systems

Maximum demand controllers, automatic power factor controllers, energy efficient motors, soft starters with energy saver, variable speed drives, energy efficient transformers, electronic ballast, occupancy sensors, energy efficient lighting controls, energy saving potential of each technology.

Course Plan

No	Topic	No. of Lectures
1	**Energy Scenario (6hours)**	
1.1	Classification of energy- primary and secondary energy, commercial and non-commercial energy, non-renewable and renewable energy with special reference to solar energy, Capacity factor of solar and wind power generators.	2
1.2	Global fuel reserve, Energy scenario in India, Impact of energy usage on climate	1
1.3	Salient features of Energy Conservation Act 2001 & The Energy Conservation (Amendment) Act, 2010 and its importance. Prominent organizations at centre and state level responsible for its implementation.	2
1.4	Standards and Labelling: Concept of star rating and its importance, Types of product available for star rating	1
2	**Energy Efficiency in Electrical Supply System and Motors (7hours)**	

2.1	Electrical system: Electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit.	2
2.2	Selection and location of capacitors, performance assessment of PF capacitors, distribution and transformer losses	2
2.2	Electric motors: Types, losses in induction motors, motor efficiency, factors affecting motor performance, rewinding and motor replacement issues, energy saving opportunities with energy efficient motors.	3
3	**Energy Efficiency in Electrical Utilities (8hours)**	
3.1	Pumps: Introduction to pump and its applications, Efficient pumping system operation, Energy efficiency in agriculture pumps, Tips for energy saving in pumps	2
3.2	Compressed Air System: Types of air compressor and its applications, Leakage test, Energy saving opportunities in compressors.	2
3.3	Energy Conservation in HVAC and Refrigeration System: Introduction, Concept of Energy Efficiency Ratio (EER), Energy saving opportunities in Heating, Ventilation and Air Conditioning (HVAC) and Refrigeration Systems	2
3.4	Fans and blowers: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities.	2
4	**Energy Efficiency in Lighting, DG systems and transformers (6hours)**	
4.1	Lighting Systems: Basic definitions- Lux, lumen and efficacy, Types of different lamps and their features, Energy efficient practices in lighting	2
4.2	DG Systems: Introduction, Energy efficiency opportunities in DG systems, Loading estimation	2
4.3	Transformers: Introduction, Losses in transformer, transformer Loading, Tips for energy savings in transformers	2
5	**Energy Efficient Technologies in Electrical Systems (7 hours)**	
5.1	Maximum demand controllers, automatic power factor controllers	1
5.2	Energy efficient motors, soft starters with energy saver	2
5.3	Variable speed drives, energy efficient transformers	2
5.4	Electronic ballast, occupancy sensors, energy efficient lighting controls	2

Reference Books

1) Guide book on General Aspects of Energy Management and Energy Audit by Bureau of Energy Efficiency, Government of India. Edition 2015

2) Guide book on Energy Efficiency in Electrical Utilities, by Bureau of Energy Efficiency, Government of India. Edition 2015

3) Guide book on Energy Efficiency in Thermal Utilities, by Bureau of Energy Efficiency, Government of India. Edition 2015

4) Handbook on Energy Audit & Environmental Management by Y P Abbi & Shashank Jain published by TERI. Latest Edition

5) S. C. Tripathy, “ Utilization of Electrical Energy and Conservation” , McGraw Hill, 1991.

Important Links:

6) Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India. www.beeindia.gov.in.

7) Ministry of New and Renewable Energy (MNRE), Government of India. www.mnre.gov.in.

8) Central Pollution Control Board (CPCB), Ministry of Environment, Forest and Climate Change,

9) Government of India. www.cpcb.nic.in.

10) Energy Efficiency Services Limited (EESL). www.eeslindia.org.

11) Electrical India, Magazine on power and electrical products industry. www.electricalindia.in.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE071	**Electric Charging Systems For Electrical Vehicles**	**INTERDISCIPLINARY ELECTIVE**	**3**	**0**	**0**	**3**

Preamble:

The course is aimed to provide an overview of the technological concepts and regulatory frameworks related to the charging systems of Electrical Vehicle

Course Outcomes:

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

CO 1	Analyze the working of different types of controlled rectifiers
CO 2	Analyze the working of different types of choppers
CO 3	Describe the energy storage mechanisms used for EV's
CO 4	Explain the various types of chargers used for EV's
CO 5	Explain the various charging standards for EV's

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination	
Apply	50%	
Analyse	30%	
Evaluate	20%	
Create		

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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: 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. 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

APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH &YEAR

Course code: 222EEE071

Course Name: Electric Charging Systems For Electrical Vehicles

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

PART A

(Answer all questions. Each question carries 5 marks)

1. What is inverted mode of operation of the converter? Explain.
2. What is a two quadrant chopper? Explain.
3. Explain about the battery management systems used in EV.
4. Draw and explain the configuration of a level-1 charger.
5. Explain the CHAdeMo charging protocol for EV.

PART –B
(Answer any five questions, each question carries 7 marks)

6. Draw the circuit of 3 phase fully controlled rectifier with RLE load and explain the working for α=600 with necessary waveforms. Derive the expression for average output voltage.
7. A boost converter has an input voltage of Vd=10V and an average output voltage of 20V and average load current of I0=0.5A.The switching frequency is 25kHz and and L=200μH and C=220μF.Determine (a) duty ratio (b) ripple current of the inductor (c) peak current of inductor and (d) ripple voltage of capacitor.
8. Draw the circuit of 3 phase fully controlled rectifier with RL load and explain the working for α=60 degree with necessary waveforms. Derive the expression for average output voltage.
9. Explain the working of a Buck-Boost regulator, showing relevant waveforms and derive the expression for its output voltage.
10. Explain about Fuel cell based energy storage systems.
11. Explain the operation of level-3 battery charger with a neat circuit diagram.
12. Describe the various charging standards used for electric vehicles.

Syllabus

Module 1- AC-DC converters

Controlled Rectifiers (Single Phase) – Half-wave controlled rectifier with R load– 1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous conduction only) – Output voltage equation – Controlled Rectifiers (3-Phase) - 3-phase half-wave controlled rectifier with R load – 3-phase fully controlled converter with RLE load (continuous conduction, ripple free) – Output voltage equation-Waveforms for various triggering angles (analysis not required).

Module 2- DC-DC converters

DC-DC converters – Step down and Step up choppers – Single-quadrant, Two-quadrant and Four quadrant chopper – Pulse width modulation & current limit control in dc-dc converters. Switching regulators – Buck, Boost & Buck-boost –Operation with continuous conduction mode – Waveforms – Design (switch selection, filter inductance and capacitance).

Module 3- Energy storage

Energy Storage**:** Introduction to energy storage requirements in Electric Vehicles- Units of Battery Energy Storage - Capacity rate- Battery based energy storage systems, Types of battery- Lifetime and Sizing Considerations - Battery Charging, Protection, and Management Systems - Fuel Cell based energy storage systems- Supercapacitors- Hybridization of different energy storage devices.

Module 4- Charging infrastructure

On-board chargers, Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack power flow block schematic diagrams – Types of charging stations - AC Level 1 & 2, DC - Level 3, Wireless charging. Plug-in Hybrid EV, V2G concept.

Module 5- Charging Standards

Charging Standards - SAE J1772, VDE-AR-E 2623-2-2, JEVS G105-1993, Types of Connectors - CHAdeMo, CCS Type1 and 2, GB/T - pin diagrams and differences, IEC 61851 - Electric vehicle conductive charging modes, IEC 61980- Electric vehicle wireless power transfer systems, IEC 62196 -AC Couplers Configuration, Combo AC-DC Couplers and IS-17017 standards for EV charging.

COURSE PLAN

No	Topic	No. of Lectures
1	**AC-DC converters**	**8**
1.1	Controlled Rectifiers (Single Phase) – Half-wave controlled rectifier with R load– 1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous conduction only) –	2
1.2	Controlled Rectifiers (Single Phase) Output voltage equation – Controlled Rectifiers, Simple numeric problems	2
1.3	3-phase half-wave controlled rectifier with R load – 3-phase fully controlled converter with RLE load (continuous conduction, ripple free)	2
1.4	Controlled Rectifiers (Three Phase) Output voltage equation- Waveforms for various triggering angles (analysis not required). Simple numeric problems	2
2	**DC-DC converters**	**7**
2.1	Step down and Step up choppers – Single-quadrant, Two-quadrant and Four quadrant chopper	2
2.2	Pulse width modulation & current limit control in dc-dc converters.	1
2.3	Switching regulators – Buck, Boost & Buck-boost	2
2.4	Operations with continuous conduction mode – Waveforms – Design (switch selection, filter inductance and capacitance).	2
3	**Energy storage**	**9**
3.1	Introduction to energy storage requirements in Electric Vehicles	1
3.2	Units of Battery Energy Storage - Capacity rate-	1
3.3	Battery based energy storage systems, Types of battery-	1
3.4	Lifetime and Sizing Considerations	2

3.5	Battery Charging, Protection, and Management Systems	2
3.6	Fuel Cell based energy storage systems- Super capacitors-	1
3.7	Hybridization of different energy storage devices	1
4	**Charging infrastructure**	**8**
4.1	On-board chargers	1
4.2	Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack.	1
4.3	Power flow block schematic diagrams	2
4.4	Types of charging stations - AC Level 1 & 2	1
4.5	Types of charging stations DC - Level 3,	1
4.6	Wireless charging.	1
4.7	Plug-in Hybrid EV, V2G concept	1
5	**Charging Standards**	**8**
5.1	SAE J1772, VDE-AR-E 2623-2-2, JEVS G105-1993,	2
5.2	Types of Connectors - CHAdeMo, CCS Type1 and 2,	1
5.3	GB/T - pin diagrams and differences,	1
5.4	IEC 61851 - Electric vehicle conductive charging modes	1
5.5	IEC 61980- Electric vehicle wireless power transfer systems,	1
5.6	IEC 62196 -AC Couplers Configuration, Combo AC DC Couplers	1
5.7	IS-17017 standards for EV charging.	1
		40

Text books:

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
3. Mehrdad Ehsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
4. John G. Hayes, Electric powertrain, Wiley.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE072	**Design And Installation Of Solar PV Systems**	**INTERDISCIPLINARY ELECTIVE**	**3**	**0**	**0**	**3**

Preamble: This course provides an introduction to the artificial intelligence techniques and its applications to power system problems.

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

CO1	Describe various RES, estimate and select solar irradiance models
CO2	Demonstrate various MPPT techniques
CO3	Use appropriate inverters for PV applications
CO4	Design of the Standalone SPV System
CO5	Evaluate the life cycle cost of Grid connected PV system

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	-	1	2	3	2	-
CO2	3	2	3	2	3	2	-
CO3	3	1	2	2	3	1	1
CO4	3	3	3	3	3	3	3
CO5	3	3	3	3	3	3	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests	End Semester Examination
Remember		
Understand	20%	30%
Apply	40%	40%
Analyse	20%	30%

Evaluate	20%	
Create		

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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: 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.

Model Question paper

QP Code:

Name:

Reg No:

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

EIGHTH SEMESTER M. TECH DEGREE

EXAMINATION, MONTH & YEAR

Course Code: 222EEE072

Course Name: Design And Installation Of Solar PV Systems

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

PART A (5 x 5 = 25 Marks)

Answer all Questions. Each question carries 5 Marks

Q.no.	Module 1	Marks
1	Discuss the importance of intelligent techniques for the estimation of solar irradiance.	5
	Module 2	
2	Sketch and explain the P-V curve for two solar cells in parallel with non-identical V-I Characteristic.	5
	Module 3	
3	Enlist the advantages and disadvantages of string inverter as a grid tide inverter	5
	Module 4	
4	A PV Cell is to be emulated with a 24V battery with a 10ohm series resistance. Calculate the Fill Factor in this case	5
	Module 5	
5	Consider a situation where one enters into an annual maintenance contract (AMC) for a particular item. The annual maintenance amount is Rs.5000 for a 5 year period. If the rate of interest is 8% and the rate of inflation is 5%, what is the present worth of the AMC?	5

PART B (7 x 5 = 35 Marks)

Answer any five full questions. Each question carries 7 Marks

6 a.	Write the applications for the following solar radiation–measuring instruments:	2

Pyrheliometer

Sunshine recorder

b. Draw the flowchart for an ANN model for estimation of solar irradiance using Backpropagation algorithm. **5**

7. A PV panel having an area of 1.5m2gives the following readings under standard test conditions. The short circuit current is 8A, the open circuit voltage is 40V, the voltage at peak power is36.5V and the current at peak power is 7A. The fill factor of the PV panel is found to be 0.72. Calculate the efficiency of the panel. **7**

8. Derive the expression for impedance seen by the solar cell utilizing the volt-sec and amp-sec balance concept, when a Buck Converter is used for MPPT operation. Sketch the operating region with Load line concept in I-V curve of Solar cell, while using Buck Converter for MPPT operation. **7**

9 a. The present cost of a solar panel is Rs 2000. If the interest rate is 8% and the inflation rate is 5% then how much must one save today in order to purchase the solar panel 5 years from now? **3**

b Explain the steps involved in design of standalone solar PV system **4**

10 Draw the functional block diagram of a 3 phase grid connected Solar P V system under d-q frame control. Explain each section in details. **7**

11. Derive the expression for impedance seen by the solar cell utilizing the volt-sec and amp-sec balance concept, when a Buck Converter is used for MPPT operation. Sketch the operating region with Load line concept in I-V curve of Solar cell, while using Buck Converter for MPPT operation **7**

12a. What are the advantages of supercapacitors and fuel cells compared to conventional battery energy storage system. **4**

b. Explain Depth of Discharge, life cycle of battery and round-trip efficiency **3**

No.	**Syllabus**
1	**Introduction to various RES, Measurement and Estimation of Solar Irradiance (10 hours)**
	Need for Renewable Energy Sources- Potential Renewable Energy Sources (RES) for Power Generation- Solar Energy,Wind Energy,Biomass Energy, Small Hydropower Plants Hydropower Project Classification, Geothermal Energy and Its Potential in India, Wave Energy, Tidal Energy-Government Initiatives for Solar Photovoltaic Systems.(2hrs) Measurement and Estimation of Solar Irradiance: The Solar Irradiance Spectrum, Solar Constant and Solar Irradiance, Depletion of Solar Radiation by the Atmosphere, Factors Affecting the Availability of Solar Energy on a Collector Surface, Radiation Instruments, Solar Irradiance Components, Instruments Used Detectors for Measuring Radiation, Measuring Diffuse Radiation (4Hrs) Mathematical Models of Solar Irradiance, Estimation of Global Irradiance,Diffuse Irradiance, Regression Models, Intelligent Modeling, Fuzzy Logic–Based Modeling of Solar Irradiance, Artificial Neural Network for Solar Energy Estimation, Generalized Neural Model(4hrs)
2	**Fundamentals of Solar Photovoltaic Cells, MPPT techniques, Modules, and Arrays (10 hours)**
	Solar PV Fundamentals: The Solar Cell, Material for the Solar Cell, PV cell characteristics and equivalent circuit, Model of PV cell, Short Circuit, Open Circuit and peak power parameters, Datasheet study, Cell efficiency, Effect of temperature, Temperature effect, Solar PV Modules, Bypass Diodes, Hot Spot Formation, Fill Factor, Solar Cell Efficiency and Losses, Methods to Increase Cell Efficiency. Standard Test Conditions (STC) of the PV Cell, Factors Affecting PV Output-Tilt Angles, Partial Shading, Effect of Light Intensity, PV Module Testing and Standards,Quality Certification, Standards, and Testing for Grid-Connected Rooftop Solar PV Systems/Power Plants (4Hrs) Maximum Power Point Tracking Techniques and Charge Controllers: MPPT and Its Importance, MPPT Techniques- Curve-Fitting Technique, Fractional Short-Circuit Current (FSCC) Technique, Fractional Open-Circuit Voltage Technique, Direct Method- Perturb and Observe, Incremental Conductance Method (4Hrs) Comparison of Various MPPT Techniques, Charge Controllers and MPPT Algorithms, Modeling and of PV System with Charge Controller (2Hrs)
3	**Converter Design for SPV System (6 hours)**

	DC to DC Converters- Classification of DC-to-DC Converters- Buck converter, Boost converter, Buck–boost converter- Uses **DC to AC Converters (inverters):** Classification of Inverters- Classification based on output voltage: Square wave inverters, Modified square wave inverters, Pure sine wave inverters. Voltage source inverter: half bridge and full bridge -Current source inverter Multilevel inverter: Diode clamped, Flying capacitor- Applications Photovoltaic (PV) Inverter-incorporating MPPT-Standalone inverter- Grid Tied inverter-string inverters, solar microinverters, and centralized inverters
4	**Energy Storage for PV Applications, Design of the Standalone SPV System (7 hours)**
	Batteries - Capacity, C-rate, Efficiency, Energy and power densities, Battery selection, Other energy storage methods, Battery Storage System, Functions Performed by Storage Batteries in a PV System-Types of Batteries- Lead-Acid Batteries, Nickel-Cadmium (Ni-Cd) Batteries, Nickel-Metal Hydride (Ni-MH) Batteries, Lithium Ion Batteries etc. Installation, Operation, and Maintenance of Batteries, System Design and Selection Criteria for Batteries, Effect of DoD Disposal of Batteries, Super Capacitors, Fuel Cells **Mounting Structure:** Assessment of Wind Loading on PV Array, Types of Module Mounting Systems, PV Array Row Spacing, Standards for Mounting Structures **Design of the Standalone SPV System**: Sizing of the PV Array- Sizing of the Battery Block-Design of the Battery Charge Controller- Design of the Inverter, Sizing PV for applications without batteries, PV system design, Load profile, Days of autonomy and recharge, Battery size, PV array size, Direct PV-battery connection, Charge controller
5	**Grid-Connected PV Systems, Life Cycle Cost Analysis (7 hours)**
	Grid connection principle, PV to grid topologies, (Basic concept of d-q theory) Complete 3ph grid connection, 1ph d-q controlled grid connection (Basic treatment only), SVPWM, Life cycle costing, Growth models, Annual payment and present worth factor, LCC with examples- Life Cycle Cost Analysis- Case Study based on Difference in Power Consumption Bill, Payback Period Calculation, Comparison of PV and Conventional Electricity Costs

Syllabus and Corse Plan

No.	Topic	No. of Lectures

1		
1.1	Introduction to various RES-Solar Energy, Wind Energy, Biomass Energy, Small Hydropower Plants Hydropower Project Classification, Geothermal Energy and Its Potential in India	2
1.2	The Solar Irradiance Spectrum, Solar Constant and Solar Irradiance, Depletion of Solar Radiation by the Atmosphere, Factors Affecting the Availability of Solar Energy on a Collector Surface,	2
1.3	Radiation Instruments, Solar Irradiance Components, Instruments Used Detectors for Measuring Radiation, Measuring Diffuse Radiation.	2
1.4	Mathematical Models of Solar Irradiance, Estimation of Global Irradiance, Diffuse Irradiance, Regression Models, Intelligent Modeling	1
1.5	Fuzzy Logic–Based Modeling of Solar Irradiance	1
1.6	Artificial Neural Network for Solar Energy Estimation, Generalized Neural Model	2
2		
2.1	The Solar Cell, Material for the Solar Cell, PV cell characteristics and equivalent circuit, Model of PV cell, Short Circuit, Open Circuit and peak power parameters, Datasheet study, Cell efficiency, Effect of temperature	1
2.2	Temperature effect, Solar PV Modules, Bypass Diodes, Hot Spot Formation, Fill Factor, Solar Cell Efficiency and Losses, Methods to Increase Cell Efficiency.	1
2.3	Standard Test Conditions (STC) of the PV Cell, Factors Affecting PV Output-Tilt Angles, Partial Shading, Effect of Light Intensity,	1
2.4	PV Module Testing and Standards, Quality Certification, Standards, and Testing for Grid-Connected Rooftop Solar PV Systems/Power Plants	1
2.5	MPPT and its Importance, MPPT Techniques- Curve-Fitting Technique, Fractional Short-Circuit Current (FSCC) Technique,	2
2.6	Fractional Open-Circuit Voltage Technique, Direct Method-Perturb and Observe, Incremental Conductance Method	2

2.7	Comparison of Various MPPT Techniques, Charge Controllers and MPPT Algorithms, Modeling and of PV System with Charge Controller	2
3		
3.1	Classification of DC-to-DC Converters- Buck converter, Boost converter, Buck–boost converter- Uses	1
3.2	Classification Inverters based on output voltage: Square wave inverters, Modified square wave inverters, Pure sine wave inverters.	1
3.3	Voltage source inverter: half bridge and full bridge -Current source inverter	1
3.4	Multilevel inverter: Diode clamped, Flying capacitor- Applications	1
3.5	Photovoltaic (PV) Inverter-incorporating MPPT-Standalone inverter- Grid Tied inverter-string inverters, solar microinverters, and centralized inverters	2
4		
4.1	Batteries - Capacity, C-rate, Efficiency, Energy and power densities, Battery selection, Other energy storage methods	1
4.2	Battery Storage System, Functions Performed by Storage Batteries in a PV System-Types of Batteries- Lead-Acid Batteries, Nickel-Cadmium (Ni-Cd) Batteries, Nickel-Metal Hydride (Ni-MH) Batteries, Lithium Ion Batteries etc.	1
4.3	Installation, Operation, and Maintenance of Batteries, System Design and Selection Criteria for Batteries, Effect of DoD Disposal of Batteries, Super Capacitors, Fuel Cells	1
4.4	Assessment of Wind Loading on PV Array, Types of Module Mounting Systems, PV Array Row Spacing, Standards for Mounting Structures	2
4.5	Sizing of the PV Array- Sizing of the Battery Block-Design of the Battery Charge Controller- Design of the Inverter, Sizing PV for applications without batteries, PV system design, Load profile, Days of autonomy and recharge, Battery size, PV array size, Direct PV-battery connection, Charge controller	2
5		

5.1	Grid connection principle, PV to grid topologies, Complete 3ph grid connection, 1ph d-q controlled grid connection, SVPWM,	2
5.2	Life cycle costing, Growth models, Annual payment and present worth factor	2
5.3	LCC with examples- Life Cycle Cost Analysis- Case Study based on Difference in Power Consumption Bill	2
5.4	Payback Period Calculation, Comparison of PV and Conventional Electricity Costs	1
		40

Text Books

1. Jamil, Majid, M Rizwan, D Kothari. *Grid Integration of Solar Photovoltaic Systems*. CRC Press, 2017.

2. Solar PV System Design _ NPTEL Lecture L Umanand

References

1. Godfrey Boyle: Renewable energy, Power for a sustainable future. Oxford University press U.K

2. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.

3. Mukherjee and Thakur: Photovoltaic Systems Analysis and Design, PHI, Eastern Economy Edition, 2012.

4. Solanki: Solar Photovoltaics- Fundamentals, Technologies and Applications, PHI, Eastern Economy Edition, 2012

5. B. H. Khan, Non-Conventional Energy Resources, 2nd edition, TMH 2013

6. O'Hayre, R.P., S. Cha, W. Colella, F.B.Prinz, Fuel Cell Fundamentals, Wiley, NY (2006).

7. Liu, H., Principles of fuel cells, Taylor & Francis, N.Y. (2006).

8. Kreith F., Goswami D.Y., Energy Management and Conservation, CRC Press 2008

9. Kothari: Renewable Energy Sources and Emerging Technologies, PHI, Eastern Economy Edition, 2012

Mini Project

COURSE CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222PEE100	**MINI PROJECT**	**PROJECT**	**0**	**0**	**4**	**2**

Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The ultimate aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects increases problem solving skills.

The introduction of mini projects ensures preparedness of students to undertake dissertation. Students should identify a topic of interest in consultation with PG Programme Coordinator that should lead to their dissertation/research project. Demonstrate the novelty of the project through the results and outputs.The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required at the end of the semester.

Evaluation Committee - Programme Coordinator, One Senior Professor and Guide.

Sl. No	Type of evaluations	Mark	Evaluation criteria
1	Interim evaluation 1	20	
2	Interim evaluation 2	20	
3	Final evaluation by a Committee	35	Will be evaluating the level of completion and demonstration of functionality/ specifications, clarity of presentation, oral examination, work knowledge and involvement
4	Report	15	the committee will be evaluating for the technical content, adequacy of references, templates followed and permitted plagiarism level(not more than 25%)
5	Supervisor/Guide	10	
	Total Marks	100	

Laboratory

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222LEE004	Advanced Control Lab	Lab 2	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:

Course Outcomes:

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

CO 1	Analyse the transient and steady state behaviour of a closed loop system.
CO 2	Design and implement advanced controllers for closed loop systems.
CO 3	Design and implement estimators for a nonlinear system.
CO 4	Apply optimisation techniques to tune controllers for closed loop 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	3	3	

CO 2			3	3	3	3	
CO 3			3	3	3	3	
CO 4			3	3	3	3	

List of Exercises/Experiments

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

1. 8 experiments are mandatory.

Experiment No.	**Name of the experiment**
1	Design and validation of an adaptive PID controller for a DC motor.
2	Simulation of a PID controller with gain scheduling for a launch vehicle.
3	Design and validation of a Model Reference Adaptive controller for a DC motor.
4	Design and validation of a speed estimator for a DC motor.
5	Design and validation of an Extended Kalman Filter for a DC-DC converter
6	Design and validation of a Sliding Mode Controller for a vector controlled Induction motor Drive.
7	Design and validation of a Model Predictive Controller for a DC motor.

8	Design and validation of a Fuzzy Logic Controller for a DC motor.
9	Design and validation of a Neural Network based controller for a DC motor.
10	Fractional order PID controller tuning for a DC motor using any one of the bio inspired optimization technique.
11	Implementation of any one of the above controllers using an embedded processor.