ECT292	NANOELECTRONICS	CATEGORY	L	T	P	CREDIT
		Honors	3	1	0	4

Preamble: This course aims to understand the physics behind mesoscopic systems and working of nanoelectronic devices.

Prerequisite: PHT100 Engineering Physics A, ECT201 Solid State Devices

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

CO 1	Explain quantum mechanical effects associated with low dimensional semiconductors.
CO 2	Explain the different processes involved in the fabrication of nanoparticles and nanolayers.
CO 3	Explain the different techniques for characterizing nano layers and particles
CO 4	Explain the different transport mechanisms in nano structures
CO 5	Illustrate the operating principle of nanoscale electronic devices like SET, Resonant tunnelling devices, Quantum lasers etc.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	20
Understand	35	35	70
Apply	5	5	10
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1): Explain the quantum mechanical effects associated with low dimensional semiconductors.

1. Derive the expression for density of states in a 1D nanomaterial.

2. Compare and contrast triangular, square and parabolic quantum wells.

3. Solve numerical problems to find whether the given material is a nanometric one.

Course Outcome 2 (CO2) : Explain the different processes involved in the fabrication of nanoparticles and nanolayers.

1. Explain Sol-Gel process for synthesis of nanoparticles.
2. Explain the different steps involved in CVD process for fabricating nanolayers.
3. DC sputtering cannot be used for the coating of non- conducting materials. Justify.

Course Outcome 3 (CO3): Explain the different techniques for characterizing nano layers and particles.

1. Illustrate the working principle of an AFM.
2. Explain the different emission and interactions between electron beam and the specimen.
3. Explain the principle of operation of an XRD.

Course Outcome 4 (CO4): Explain the different transport mechanisms in nano structures.

1. Explain Kronig Penney model of a super lattice.

2. Explain modulation doping with an example.

3. Explain the different scattering events encountered by a carrier during parallel transport under the influence of electric field.

Course Outcome 5 (CO5): Illustrate the operating principle of nanoscale electronic devices like SET, Resonant tunnelling devices, Quantum lasers etc.

1. Explain Coulomb blockade effect. Illustrate the working of a single electron transistor.

2. Draw the schematic representation of the conduction band of a resonant tunnel diode for (a) no voltage applied (b) increasing applied voltages. Explain its I-V characteristics.

3. MODFETS are high electron mobility transistors. Justify.

Syllabus

Module I

Introduction to nanotechnology, Limitations of conventional microelectronics, characteristic lengths in mesoscopic systems, Quantum mechanical coherence.

Low dimensional structures - Quantum wells, wires and dots, Density of states of 1D and 2D nanostructures.

Basic properties of square quantum wells of finite depth, parabolic and triangular quantum wells

Module II

Introduction to methods of fabrication of nano-layers: physical vapour deposition- evaporation & Sputtering, Chemical vapour deposition, Molecular Beam Epitaxy, Ion Implantation, Formation of Silicon Dioxide- dry and wet oxidation methods.

Fabrication of nano particle- grinding with iron balls, laser ablation, reduction methods, sol gel, self assembly, precipitation of quantum dots.

Module III

Introduction to characterization of nanostructures: Principle of operation of Scanning Tunnelling Microscope, Atomic Force Microscope, Scanning Electron microscope - specimen interaction, X-Ray Diffraction analysis

Module IV

Quantum wells, multiple quantum wells, Modulation doped quantum wells, concept of super lattices Kronig - Penney model of super lattice.

Transport of charge in Nanostructures - Electron scattering mechanisms, Hot electrons, Resonant tunnelling transport, Coulomb blockade, Effect of magnetic field on a crystal. Aharonov-Bohm effect, the Shubnikov-de Hass effect.

Module V

Nanoelectonic devices - MODFETS, Single Electron Transistor, CNT transistors – Properties of graphene
Resonant tunnel effect, RTD, RTT, Hot electron transistors
Quantum well laser, quantum dot LED, quantum dot laser

Text Books

1. J.M. Martinez-Duart, R.J. Martin Palma, F. Agulle Rueda Nanotechnology for Microelectronics and optoelectronics , Elsevier, 2006
2. W.R. Fahrner, Nanotechnology and Nanoelctronics, Springer, 2005

Reference Books

1. Chattopadhyay, Banerjee, Introduction to Nanoscience & Technology, PHI 2012
2. Poole, Introduction to Nanotechnology, John Wiley 2006.
3. George W. Hanson, Fundamentals of Nanoelectronics, Pearson Education, 2009.
4. K. Goser, P. Glosekotter, J. Dienstuhl, Nanoelectronics and nanosystems, Springer 2004.
5. Supriyo Dutta, Quantum Transport- Atom to transistor, Cambridge, 2013.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**MODULE 1**	
1.1	Introduction to nanotechnology, Limitations of conventional microelectronics	1
1.2	Characteristic lengths in mesoscopic systems	1
1.3	Quantum mechanical coherence, Schrodinger's equation, Low dimensional structures - Quantum wells, wires and dots	3
1.4	Density of states of 1D and 2D nanostructures	2
1.5	Basic properties of square quantum wells of finite depth, parabolic and triangular quantum wells	3
2	**MODULE 2**	
2.1	Introduction to methods of fabrication of nano-layers: physical vapour deposition- evaporation & Sputtering,	2
2.2	Chemical vapour deposition, Molecular Beam Epitaxy	2
2.3	Ion Implantation, Formation of Silicon Dioxide- dry and wet oxidation methods	2
2.4	Fabrication of nano particle- grinding with iron balls, laser ablation, reduction methods	2
2.5	Sol - Gel, self assembly, precipitation of quantum dots.	2
3	**MODULE 3**	
3.1	Introduction to characterization of nanostructures: Principle of operation	2

	of Scanning Tunnelling Microscope	
3.2	Atomic Force Microscope	1
3.3	Scanning Electron microscope - specimen interaction.	1
3.4	X-Ray Diffraction analysis	1
4	**MODULE 4**	
4.1	Quantum wells, multiple quantum wells, Modulation doped quantum wells, concept of super lattices	2
4.2	Kronig - Penney model of super lattice.	1
4.3	Transport of charge in Nanostructures - Electron scattering mechanisms, Hot electrons	1
4.4	Resonant tunnelling transport, Coulomb blockade	2
4.5	Quantum transport in nanostructures - Coulomb blockade	1
4.6	Effect of magnetic field on a crystal. Aharonov-Bohm effect	2
4.7	Shubnikov-de Hass effect	1
5	**MODULE 5**	
5.1	Nano electonic devices- MODFETS	2
5.2	Single Electron Transistor	1
5.3	CNT transistors , Properties of graphene	2
5.4	RTD, RTT, Hot electron transistors	3
5.5	Quantum well laser, quantum dot LED, quantum dot laser	2

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

MODEL QUESTION PAPER

ECT 292 NANOELECTRONICS

Time: 3 hours **Max. Marks:100**

PART A

Answer ***all*** questions. Each question carries ***3 marks***.

1. Explain any three characteristic lengths in mesoscopic systems.
2. Explain the terms (i) coherence length (ii) phase coherence.
3. Explain Laser ablation method for nanoparticle fabrication.
4. DC sputtering cannot be used for coating of non-conducting materials. Justify
5. Explain two different modes of operation of a STM.
6. Explain XRD method for characterizing nano materials.
7. Differentiate between the two types of multiple quantum wells.
8. Explain Aharonov-Bohm effect.
9. Explain why MODFETs are called high electron mobility transistors.
10. List any six properties of graphene.

PART B

Answer ***any one*** question from each module. Each question carries 14 marks.

MODULE I

11. (a) Show that DOS in a 2D material is independent of energy. (8 marks)
(b) Explain any three physical limitations in reducing the size of devices in Nano metric scale. (6 marks)

12. Compare and contrast square, parabolic and triangular quantum wells (14 marks)

MODULE III

13. (a) Illustrate the process of Molecular Beam Epitaxi for fabricating nano layers. (8 marks)
(b) Differentiate between dry oxidation and wet oxidation techniques (6 marks)

14. (a) Sketch and label a CVD reactor and explain the different steps involved in the CVD process. (8 marks)
(b) Explain the reduction method for nano particle fabrication (6 marks)

MODULE III

15. Explain the different specimen interactions of an electron beam and illustrate the working of a SEM (14 marks)

16. Explain the principle of operation of an AFM. Explain the different modes of operation. (14 marks)

MODULE IV

17. (a) Explain Kronig–Penney model of a super lattice. What is meant by Zone folding? (10 marks)

(b)Explain the concept of hot electrons in parallel transport (4 marks)

18. (a) Explain Coulomb Blockade effect (8 marks)

(b) Illustrate resonant tunneling effect. (6 marks)

MODULE V

19. (a)) Draw the schematic and explain the working of a single electron transistor (8 marks)

(b) Explain working of resonant tunneling diodes (6 marks)

20. (a) Illustrate the working of a quantum well laser (6 marks)

(b) Explain the different types of Carbon Nanotube transistors (8 marks)

ECT294	STOCHASTIC PROCESSES FOR COMMUNICATION	CATEGORY	L	T	P	CREDIT
		Honors	3	1	0	4

Preamble: This course aims to apply the concepts of probability and random processes in communication systems.

Prerequisite: None

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

CO 1	Explain the concepts of probability, random variables and stochastic processes
CO 2	Apply the knowledge in probability to ststistically characterize communication channels.
CO 3	Apply probability to find the information and entropy
CO 4	Explain source coding and channel coding theorem.
CO 5	Apply stochastic processes in data transmission

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember	10	10	20
Understand	25	25	50
Apply	15	15	30
Analyse			
Evaluate			
Create			

Mark distribution

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

Continuous Internal Evaluation Pattern:

Attendance : 10 marks

Continuous Assessment Test (2 numbers) : 25 marks

Assignment/Quiz/Course project : 15 marks

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

Course Level Assessment Questions

Course Outcome 1 (CO1): Concepts in probability

1. Give frequentist and axiomatic definitions of probability. State the demerits of frequentist definition.
2. What is a random variable? Illustrate with an example how it becomes useful in studying engineering problems?
3. A six faced die with P(1)=P(3)=1/3, P(4)=P(5)=1/4 is thrown in a game with outcomes listed in the table.

Face	1	2	3	4	5	6
Payoff(Rs)	+50	-40	+60	-60	-20	+100

The + and - signs indicates gain and loss for the the player respectively.

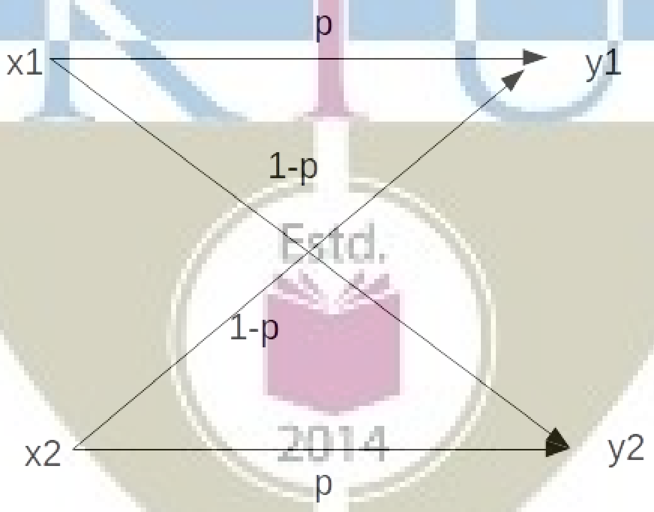
1.Draw the CDF and PDF
2. Compute the expected value of gain/loss. Is it worthwhile to play the game?
3. Compute the entropy of the random variable.

Course Outcome 2 (CO2) : Review of random processes

1. Give the conditions for WSS and SSS.
2. Test if the sinusoid $X(t)=A\cos(2\pi ft+\theta)$ with θ variying uniformly in the interval $[-\pi,\pi]$ is WSS.
3. Define white Gussian noise.
4. State central limit theorem. Why is Guassian model suitable in additive noise channels?

Course Outcome 3 (CO3): Entropy and Information

1. Define discrete memoryless source and discrete menoryless channel.
2. Define entropy and conditional entropy.
3. See the binary symmetric channel in the figure below.



Let p(x1)=1/3 and p =1/4. Compute the mutual information betweeen X and Y.

Course Outcome 4 (CO4): Source coding and Channel Coding

1. State the souce coding theorem.
2. Compute the mutual information between the input and output of an AWGN channel. What is its capacity.
3. Find the capacity of an AWGN channel with 4kHz bandwidth and the noise power spectral density 10^{-12}W/Hz. The signal power at the receiver is 0.1mW.

Course Outcome 5 (CO5): Stochastic processes in data transmission

1. Derive Chapman – Kolmogorov equation.

2. Explain the packet transmission in a slotted ALOHA network
3. Consider a Markov chain with three possible states 1,2,3 with transition probability matrix

$$\begin{pmatrix} \frac{1}{4} & \frac{1}{2} & \frac{1}{4} \\ \frac{1}{3} & 0 & \frac{2}{3} \\ \frac{1}{2} & 0 & \frac{1}{2} \end{pmatrix}$$

a) Draw the state transition diagram.
b) Find $P(X_4=3|X_3=2)$
c) If $P(X_0=1)=1/3$ Find $P(X_0=1,X_1=2)$

SYLLABUS

Module 1 : Review of Probability and Random Variables [1,2]

Review of probability. Relative frequency and Axiomatic definitions of probability, Significance of axiomatic definition. Bayes theorem and conditional probability. Independence. Discrete random variables. The cumulative distribution and density functions for discrete random variables. Joint distribution and conditional distribution. Statistical averages. Mean, Variance and standard deviation, Gaussian density function, Pdf of envelop of two gaussian variables – Rayleigh pdf.

Module 2 : Review of Random Processes [1-3]

Stochastic Processes. Stationarity and ergodicity. WSS and SSS processes. Gaussian Random process, Mean and autocorrelation and power spectral density functions. Weiner Kinchine theorem, Bandwidth of a random process, PSD of a Pulse Amplitude Modulated wave. White noise, Filtering of discrete WSS process by LTI systems. Noise-equivalent bandwidth, Signal to Noise Ratio, Matched Filter, Bandlimited and narrowband random process.

Sum of random variables, Markov Inequality, Chebyshev Inequality, Convergence, The central limit theorem (statement only). Gaussianity of thermal noise.

Module 3: Entropy and Information [1-3]

Basics of discrete communication system, Sources, channels and receivers. Discrete memoryless sources. Entropy. Source coding theorem (statement only). Mutual Information. Discrete memoryless channels. Matrix of channel transmission probabilities. Noiseless and noisy channels, binary symmetry channels. Channel coding theorem (statement only) Channel capacity for BSC (derivation reqruired), Differential entropy, Channel capacity of AWGN channel (statement only).

Module 4 : Markov Process and Queuing Theory [4,5]

Markov process. Definition and model. Markov chain. Transition probability matrix. State diagram and characteristics of a Markov chain. Chapman Kolmogorov equation. Poisson process.

Module 5 : Queues in Communication Networks [4,5]

Overview of queuing theory. M/M/1, M/M/∞, Application to packet transmission in a slotted ALOHA computer communication network.

Text Books

1. Papaulis and Unnikrishna Pillai, "Probability, Random Variables and Stochastic Processes", MH
2. Analog and Digital Communication Systems, Hsu, Schaum Outline Series, MGH.
3. Digital Communication, John G Proakis, John Wiley
4. Probability and Random Processes, Miiller and Childers, Ed., 2, Academic Press
5. Data Networks, Bertsekas and Gallager, Ed. 2, PHI

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Review of probability. Relative frequency and Axiomatic definitions of probability, Significance of axiomatic definition.	1
1.2	Bayes theorem and conditional probability. Independence.	1
1.3	Discrete random variables.	1
1.4	The cumulative distribution and density functions for discrete random variables. Joint distribution and conditional distribution.	3
1.5	Statistical averages. Mean, Variance and standard deviation,	2
1.6	Gaussian density function, Pdf of envelop of two gaussian variables – Rayleigh pdf.	2
2	**MODULE 2**	
2.1	Stochastic Processes. Stationarity and ergodicity. WSS and SSS processes. Gaussian Random process	2
2.2	Mean and autocorrelation and power spectral density functions. Weiner Kinchine theorem, Bandwidth of a random process, PSD of a Pulse Amplitude Modulated wave.	3
2.3	White noise, Filtering of discrete WSS process by LTI systems. Noise-equivalent bandwidth, Signal to Noise Ratio, Matched Filter, Bandlimited and narrowband random process.	3
2.4	Sum of random variables, Markov Inequality, Chebyshev Inequality, Convergence, The central limit theorem (statement only). Gaussianity of thermal noise.	2
3	**MODULE 3**	
3.1	Basics of discrete communication system, Sources, channels and receivers.	1
3.2	Discrete memoryless sources. Entropy. Source coding theorem (statement only).	1

3.3	Mutual Information. Discrete memoryless channels. Matrix of channel transmission probabilities. Noiseless and noisy channels, binary symmetry channels.	2
3.4	Channel coding theorem (statement only) Channel capacity for BSC (derivation reqruired),	1
3.5	Differential entropy, Channel capacity of AWGN channel (statement only).	2
4	**MODULE 4**	
4.1	Markov process. Definition and model.	1
4.2	Markov chain. Transition probability matrix. State diagram and characteristics of a Markov chain. Chapman Kolmogorov equation.	4
4.3	Poisson process	3
5	**MODULE 5**	
5.1	Overview of queuing theory.	2
5.2	M/M/1, M/M/∞ systems	3
5.3	Application to packet transmission in a slotted ALOHA computer communication network.	3

Simulation Assignments

The following simulations can be done Python/R/MATLAB/SCILAB.

Generation of Discrete Stochastic Signals

1. Simulate stochastic signals of
   - Uniform
   - Binomial
   - Gaussian
   - Rayleigh
   - Ricean

   probability density functions and test their histograms.
2. Compute the statistical averages such as mean, variance, standard deviation etc.
3. To compute the autocorrelation matrix for each signals. Compare the autocorrelation of Gaussian signal with others.
4. To observe the spectrum of the signal and relate it with the autocorrelation function.

Central Limit Theorem–Gaussianity of Channels

- Simulate a coin toss experiment that generates a string of length N of 0s and 1s that are uniformly distributed.
- Toss the coin M times and sum up the string in every toss.
- Plot the normalized histogram of the sum values for $M = 100, 1000, 5000$.Observe that it is a Binomial distribution.
- Plot the function $q = \binom{M}{r} p^r (1-p)^{M-r}$ and compare with the histogram.
- Make M very large and observe that the histogram tends to become Gaussian, justifying the central limit theorem.

Frequency of Characters in English Text and the Entropy

1. It is required to understand the probabilities of occurrence of characters in English text say an English novel say with more than 300 pages(that contains text only) in .txt format(student may download one such file.).
2. Read the novel in *.txt* format into a single string or array and to identify the unique symbols(all letters, numbers, punctuation marks etc.) in the file and to plot their frequencies of occurrence.
3. Aprreciate the probabilities of occurrences of all symbols.
4. Compute the entropy and the information content in the book.

Simulation of a Point Process

1. It is required to simulate a point Poisson process, say the arrival of packets in a queue.
2. Let the rate of arrival of packets be say 100 per second.
3. Simulate the Poisson process using small time bins of say 1 millisecond.
4. Since Poisson process has no memory, the occurrence of an event is independent from one bin to another.
5. Binary random signals can be used to represent success or failure.
6. Simulate and dispaly each event with a vertical line using say *matplotlib*
7. Generate the couting process $N(t)$ which is the sum of the events until time t.
8. Plot $N(t)$ against t and appreciate it.

Simulation of a Discrete Markov Chain

1. It is required to simulate a birth death process as a discrete Markov chain.
2. Let us consider that the total population cannot exceed 1000 and the initial poulation is 100.
3. Set equal birth and death rates.
4. Iterate for say 10000 steps and plot the population against the iteration number.
5. Repeat the simulation for different rates and different population aand iteration sizes and appreciate the results.

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd. 2014

Model Question Paper

A P J Abdul Kalam Technological University

Fourth Semester B Tech Degree Examination

Branch: Electronics and Communication

Course: ECT 294 Stochastic Processes for Communication

Time: 3 Hrs **Max. Marks: 100**

PART A

Answer All Questions

1	Give the three definitions of probability	(3)	K_2
2	In the toss of an unnfair coin, the probability of head is $\frac{1}{3}$.The player gets Rs. 100 if head turns up and loses Rs. 200 if tail turns up. Draw the CDF and PDF of this random variable	(3)	K_3
3	Write the conditions for strict sense and wide sense stationarity	(3)	K_2
4	Explain the Gaussian statistics of communication channels	(3)	K_2
5	State the two source coding theorems	(3)	K_1
6	Give channel matrix of a noiseless binary channel	(3)	K_2
7	With mathematical model, explain Markov process	(3)	K_2
8	Give an example of a Markov chain with its transition probability matrix	(3)	K_2
9	Explain an M/M/1 queue system in packet transmission	(3)	K_2
10	Explain the statistics of packet arrival in M/M/1 queue system	(3)	K_2

PART B

Answer one question from each module. Each question carries 14 mark.

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Module I

11 A random variable $\mathbf{X}$ has the following pdf.

$$f_{\mathbf{X}}(\lambda) = \begin{cases} A[1 - \frac{|\lambda|}{3}]; & -3 \leq \lambda \leq 3 \\ 0; & \text{else} \end{cases}$$

Find the probability $P[|\lambda| < 1.5]$ (4) K_3

Find the probability $P[1.2 \leq \lambda \leq 2.3]$ (4) K_3

Find $E[\mathbf{X}]$ (6) K_3

OR

12. A six faced die with $P(1) = P(3) = \frac{1}{6}$, $P(4) = P(5) = \frac{1}{8}$, $P(2) = \frac{1}{12}$ is thrown in a game with outcomes listed in the table.

Face	1	2	3	4	5	6
Payoff	50	-40	60	-60	-20	100

The + and - signs indicates gain and loss for the player respectively.

A Draw the CDF and PDF of the Payoff random variable. (6) K_3

B Compute the expected value of gain/loss. Is it worthwhile to play the game? (5) K_3

C Compute the variance of Payoff. (3) K_3

Estd. 2014

Module II

13(A) Test if the random process (8) K_3

$$X(t) = A\cos(2\pi f_c t + \theta)$$

is WSS with θ a uniformly distributed random variable in the interval $[-\pi, \pi]$.

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13(B) If a random signal is applied as input to an LTI system, how is the power spectral density of the output related to that of the input? Explain. (6) K_2

OR

14(A) State and prove Wiener Kinchine theorem . (8) K_3

14(B) Justify the suitability of using white Gaussian model for noise in a communication system. (6) K_2

Module III

15(A) State source coding theorem for a discrete memoryless source. (6) K_2

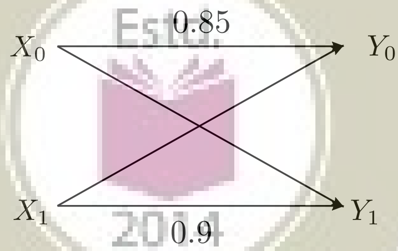
15(A) Show that mutual information is always positive. (3) K_2

15(C) What is channel capacity in terms of the conditional entropy? Write down the capacity of an AWGN channel. (5) K_3

OR

16(A) Define entropy of a discrete memoryless source. If the alphabet is finite with size K, show that $H(X) \leq \log_2 K$ (6) K_2

16(B) For the binary channel below, compute the channel transition matrix and $P(Y_0)$ and $P(Y_1)$, given that $P(X_0) = P(X_1) = 0.5$ (8) K_3



Module IV

17(A) Explain a Poisson random process. Give two practical examples of a Poisson process (7) K_2

17(B) Derive Chapman – Kolmogorov equation. (7) K_3

OR

18 Consider a Markov chain with three possible states 1,2,3 with transition probability matrix

(A) Draw the state transition diagram. (4) K_2

(B) Find $P(X4 = 3|X3 = 2)$ (5) K_3

(C) If $P(X0 = 1) = \frac{1}{3}$, find $P(X0 = 1, X1 = 2)$ (5) K_3

Module V

19 Explain the packet transmission in a slotted ALOHA network (14) K_2

OR

20 Explain the M/M/1 queue system pertaining to packet transmission (14) K_2

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd. 2014

ECT296	STOCHASTIC SIGNAL PROCESSESING	CATEGORY	L	T	P	CREDIT
		Honours	3	1	0	4

Preamble: This course aims to study stochastic signals and their interactions with LTI systems

Prerequisite: None

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

CO 1	Explain the concepts of probability, random variables and stochastic processes
CO 2	Apply the knowledge in probability to ststistically characterize communication channels.
CO 3	Use the properties of WSS for finding the LTI system response
CO 4	Model discrete signals using various methods
CO 5	Estimate the spectra of signals using various methods.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	20
Understand	15	15	30
Apply	25	25	50
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1): Concepts in probability

1. Give frequentist and axiomatic definitions of probability. State the demerits of frequentist definition.
2. What is a random variable? With an example, illustrate how it finds application in defining engineering problems?
3. A six faced die with P(1)=P(3)=1/3, P(4)=P(5)=1/4 is thrown in a game with outcomes listed in the table.

Face	1	2	3	4	5	6
Payoff(Rs)	+50	-40	+60	-60	-20	+100

The + and - signs indicates gain and loss for the the player respectively.

1.Draw the CDF and PDF

2. Compute the expected value of gain/loss. Is it worthwhile to play the game?
3. Compute the entropy of the random variable.

Course Outcome 2 (CO2) : Review of random processes

1. State central limit theorem. Explain the validity of using Gaussian model for additive communication channels.
2. Give the conditions for WSS and SSS.
3. Test if the sinusoid $X(t)=A\cos(2\pi ft+\theta)$ with θ variying uniformly in the interval [-π,π] is WSS.

Course Outcome 3 (CO3): WSS and LTI systems

1. Derive Wiener Hopf equations.
2. Solve Wiener-Hopf equation to get a third order discrete system for a an RV X whose autocorrelation is Rx=[0.89,0.75,0.7,0.6]
3. Prove that autocorretion and power spectral density are Fourier transform pairs

Course Outcome 4 (CO4): Signal modeling

1. Use Prony method to model a unit pulse x[n]=U[n]-U[n-N] as a system with one pole and one zero.
2. Use Pade apprimation to model the signal x whose fisrt six values are [1,1.2,0.9,0.5,0.6,0.25] using a second order all pole model (p=2 and q=0)

Course Outcome 5 (CO5): Stochastic processes in data transmission

1. Explain the periodogram method of spectrum estimation
2. Explain the need pf spectrum estimation
3. Use ARMA(p,q) model to estimate the spectrum

Syllabus

Module 1 : Review of Probability and Random Variables [1]

Review of probability. Relative frequency and Axiomatic definitions of probability, Significance of axiomatic definition. Bayes theorem and conditional probability. Independence. Discrete random variables. The cumulative distribution and density functions for random variables. Joint distribution and conditional distribution. Statistical averages. Mean, Variance and standard deviation, Functions of random variables. Multivariate Gaussian density function.

Module 2 : Review of Random Processes [1]

Stochastic Processes. Stationarity and ergodicity. WSS and SSS processes. Discrete Gaussian, Rayleigh and Ricean processes.

Sums of random variables, Convergence, Markov and Chebyshev inequality, The central limit theorem (statement only).

Module 3: The Autocorrelation Matrix and its Significance [2]

Statistical averages of discrete stationary stochastic processes. Mean and autocorrelation and power spectral density functions. Weiner Kinchine theorem, Filtering of discrete WSS process by LTI systems. The autocorrelation matrix and the significance of its eigen vectors. Whitening. Properties of autocorrelation matrix, its inversion and Levinson-Durbin Recursion. Wiener-Hopf equation. Brownian motion, its mathematical model and its autocorrelation and power spectral density

Module 4 : Signal Modeling - Deterministic and Stochastic [1]

The least square method of signal modeling. The Pade approximation. Prony's method. Stochastic models, AR, MA and ARMA models.

Module 5 : Spectrum Estimation [1,2]

Periodogram method of spectrum estimation. Parametric methods AR, MA and ARMA methods

Text Books

1. Monson Hayes, “Statistical Digital Signal Processing”, Wiley
2. A. Papaulis and Unnikrishna Pillai, “Probability, Random Variables and Stochastic Processes”, McGraw Hill

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Probability and Random Processes**	
1.1	The three definitions. Critique to classical definition. Probability as a function. The domain of probability function. Event and probability space	2
1.2	Conditional probability, Bayes theorem, Meaning and significance of prior. Random variable. Definition. Random variable as a function and its domain. Comparison with probability function.	2
1.3	Examples of RV. Discrete and continuous RV. CDF and PDF of RV(both discrete and continuous) Examples. Relation between the two and properties	1
1.4	Uniform and Gaussian Pdf and correspoding CDF. Properties	1
	Expectation, variance and standard deviation, Examples	2
1.5	Functions of random variables.	2
2	**Stochastic Processes**	
2.1	Stochastic process, Definition. Stationarity and ergodicity	2
2.2	WSS and SSS conditions. Example problems	2
2.3	Sums of random variables, Convergence, Markov and Chebyshev inequality	2
2.4	Gaussian Process. Envelope of Gaussian process. Rayleigh pdf. Example	2

2.5	Central limit theorem. Application in AWGN channel	1
3	**Autocorrelation Matrix**	
3.1	Expectation, variance, autocorrelation and power spectral density	2
3.2	Autocorrelation matrix, properties eigen values	2
3.3	Filtering of WSS, output auotocorrelation and PSD	2
3.4	Inversion of autocorrelation matrix. LD recursion	2
3.5	Whitening	1
3.6	Wiener Hopf equation, Brownian motion. Model and spectral density	3
4	**Signal Modeling**	
4.1	Least squares method	2
4.2	Pade method, Prony method	3
4.3	Stochastic models	3
5	**Spectrum Estimation**	
5.1	Periodogram	3
5.2	Parametric methods	4

Simulation Assignments

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The following simulations can be done Python/R/MATLAB/SCILAB.

Generation of Discrete Stochastic Signals

1. Simulate stochastic signals of
   - Uniform
   - Binomial
   - Gaussian
   - Rayleigh
   - Ricean

   probability density functions and test their histograms.

2. Compute the statistical averages such as mean, variance, standard deviation etc.

3. To compute the autocorrelation matrix for each signals. Compare the autocorrelation of Gaussian signal with others.

4. To observe the spectrum of the signal and relate it with the autocorrelation function.

Gambler's Trouble

- It is observed by gamblers that although the number of triples of integers from 1 to 6 with sum 9 is the same as the number of such triples with sum 10, when three dice are rolled, a 9 seemed to come up less often than a 10.
- Simulate a die throwing experiment. One may use the *randint* command in Python.
- Roll three dice together N times.
- Compute the number of times the sum of outcomes is 9 and the corresponding probability.
- Repeat the experiment for the sum of outcomes equal to 10 and observe if the hypothesis is true.
- Compute the two probabilities for $N = 100; 1000; 10000; 50000; 100000$ and plot the two probabilities against N and appreciate.

Central Limit Theorem

- Simulate a coin toss experiment that generates a string of length N of 0s and 1s that are uniformly distributed.
- Toss the coin M times and sum up the string in every toss.
- Plot the normalized histogram of the sum values for $M = 100, 1000, 5000$.Observe that it is a Binomial distribution.
- Plot the function $q = \binom{M}{r} p^r (1-p)^{M-r}$ and compare with the histogram.
- Make M very large and observe that the histogram tends to become Gaussian, justifying the central limit theorem.

Labouchere system

- Labouchere system is a betting game in which a sequence of numbers is written and the player bets for an amount equal to the first and last number written.
- The game may be tossing a coin.
- If the player wins, the two numbers are removed from the list and the player is free to continue. If the list has only one number that becomes the stake amount.
- If he fails the amount at stake is appended to the list and the game continues until the list is completely crossed out, at which point the player has got the desired money or until he runs out of money
- Simulate this game and observe the outcomes for different sequences on the list

Levinson Durbin Recursion

1. It is required to invert large autocorrelation matrices with LD recursion.
2. Realize Gaussian and uniformly distributed random signals and compute their autocorrelation matrices.
3. Load a speech signal in say *.wav* format and compute its autocorrelation matrix.
4. Create a function to perform LD recursion on the above three matrices.

Simulation of Brownian Motion

1. The task is to realize the differential/difference equation for Brownian motion in two dimensions with and without gravity.
2. Observe the particle movement on the GUI and understand.
3. Compute the autocorrelation and power spectral density and appreciate.

Spectrum Estimation

1. Generate a cosinusoid of say 100 Hz frequency and bury it in AWGN of comparable variance.
2. Write functions for periodogram and ARMA method to estimate the spectrum of the cosinusoid.
3. The student may install the Python package *spectrum* and repeat the estimations steps using its modules and compare the plot of spectra with those resulted by your functions.

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd 2014

Model Question Paper

A P J Abdul Kalam Technological University

Fourth Semester B Tech Degree Examination

Branch: Electronics and Communication

Course: ECT 296 Stochastic Signal Processing

Time: 3 Hrs **Max. Marks: 100**

PART A

Answer All Questions

1	Give the three axioms of probability	(3)	K_2
2	You throw a coin and if head turns up you get Rs. 100 and loses Rs. 40 if tails turns up. The probability of a head is is 0.2. Draw the CDF and PDF of the random variable representing gain/loss.	(3)	K_3
3	State central limit theorem. Give its significance.	(3)	K_2
4	Draw the pdf of Rayleigh density function.	(3)	K_2
5	Write and explain the differential equation for Brownian motion	(3)	K_2
6	Give the output mean and autocorrelation of a an LTI system that is driven by a WSS process.	(3)	K_2
7	Explain the term signal modeling	(3)	K_2
8	Explain ARMA model of a signal	(3)	K_2
9	Explain the need for power spectrum estimation	(3)	K_2
10	List the various parametric spectrum estimation methods.	(3)	K_2

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY Estd. 2014

PART B

Answer one question from each module. Each question carries 14 mark.

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Module I

11(A) Derive mean and variance of a Gaussian distribution with parameters μ and σ^2 (8) K_3

11(B) Write down the probability density of a bivariate Gaussian random variable. What is the signifance of the correlation coefficient? (6) K_3

OR

12. A six faced die with $P(1) = P(5) = \frac{1}{6}$, $P(4) = P(3) = \frac{1}{8}$, $P(2) = \frac{1}{12}$ is thrown in a game with outcomes listed in the table.

Face	1	2	3	4	5	6
Payoff	50	-40	60	-60	-20	100

The + and - signs indicates gain and loss for the the player respectively.

A Draw the CDF and PDF of Payoff random variable. (6) K_3

B Compute the expected value of gain/loss. Is it worthwhile to play the game? (6) K_3

C What is the variance of Payoff? (3) K_3

Estd. 2014

Module II

13(A) Test if the random process (7) K_3

$$X(t) = A\cos(2\pi f_c t + \theta)$$

is WSS with A a random variable in the interval $[-\pi, \pi]$.

13(B) If $\mathbf{X}$ and $\mathbf{Y}$ are zero mean Gaussian RVs, compute the pdf of $\mathbf{Z} = \sqrt{\mathbf{X^2} + \mathbf{Y^2}}$ (7) K_2

OR

14(A)	Express a Binomial random variable X as a sum of many Bernoulli random variables. Derive the mean of X using this connection.	(4)	K_3
14(B)	Derive Chebyshev inequality. How is it helpful in estimating tail probabilities?	(6)	K_3
14(B)	List the conditions for a stochastic process to be WSS.	(4)	K_3

Module III

15(A)	State and prove three properties of autocorrelation matrix.	(8)	K_3
15(B)	Prove that the power spectrum of a real process $\mathbf{X(t)}$ is real.	(6)	K_3

OR

16	Give the mathematical model and compute the autocorrelation of the Brownian motion	(14)	K_3

Module IV

17	Use Pade approximation to model the signal x whose fisrt six values are $[1, 1.6, 0.7, 0.4, 0.6, 0.25]$ using a second order all pole model ($p = 2$ and $q = 0$) and a second order MA model ($p = 0$ and $q = 2$)	(14)	K_3

OR

18	Use Prony method to model a unit pulse $x[n] = U[n] - U[n-N]$ as a system with one pole and one zero.	(14)	K_3

Module V

19	Explain the periodogram method of spectrum estimation	(14)	K_2

OR

20	Explain the three nonparametric methods of spectrum estimation	(14)	K_2

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd. 2014

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SEMESTER V

HONOURS

ECT393	FPGA BASED SYSTEM DESIGN	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: This course aims to develop the skill of FPGA based system design.

Prerequisite: ECT203 Logic Circuit Design

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

CO 1	Design simple digital systems with programmable logic devices
CO 2	Analyze the architecture of FPGA
CO 3	Analyze the design considerations of FPGA
CO4	Design simple combinational and sequential circuits using FPGA

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category		Continuous Assessment Tests		End Semester Examination
		1	2	
Remember	K1	10	10	10
Understand	K2	30	30	60
Apply	K3	10	10	30
Analyze	K4			
Evaluate				
Create				

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1): Design simple digital systems with programmable logic devices.

1. Design a decade counter using Verilog.
2. Implement a full adder using ROM

Course Outcome 2 (CO2): Analyze the architecture of FPGA

1. Compare coarse and fine grained FPGA.
2. Explain the architecture of logic block of FPGA

Course Outcome 3 (CO3): Analyze the design considerations of FPGA

1. What are the vendor specific issues in FPGA design.
2. Analyze Timing and Power dissipation in a typical FPGA.

Course Outcome 4 (CO4): Design simple combinational and sequential circuits using FPGA.

1. Implement a counter in Xilinx Virtex.
2. Explain how sequential circuit can be mapped into Xilinx Virtex LUT.

SYLLABUS

Module 1:

Introduction: Digital system design options and tradeoffs, Design methodology and technology overview, High Level System Architecture and Specification: Behavioral modelling and simulation, Hardware description languages (emphasis on Verilog), combinational and sequential design, state machine design, synthesis issues, test benches.

Module 2:

Programmable logic Devices: ROM, PLA, PAL, CPLD, FPGA Features, Limitations, Architectures and Programming. Implementation of MSI circuits using Programmable logic Devices.

Module 3:

FPGA architecture: FPGA Architectural options, granularity of function and wiring resources, coarse V/s fine grained, vendor specific issues (emphasis on Xilinx and Altera), Logic block architecture: FPGA logic cells, timing models, power dissipation I/O block architecture: Input and Output cell characteristics, clock input, Timing, Power dissipation.

Module 4:

Placement and Routing: Programmable interconnect - Partitioning and Placement, Routing resources, delays; Applications -Embedded system design using FPGAs, DSP using FPGAs.

Module 5:

Commercial FPGAs: Xilinx, Altera, Actel (Different series description only), Case study Xilinx Virtex: implementation of simple combinational and sequential circuits.

Text Books

1. FPGA-Based System Design Wayne Wolf, Verlag: Prentice Hall
2. Modern VLSI Design: System-on-Chip Design (3rd Edition) Wayne Wolf, Verlag

Reference Books

1. Field Programmable Gate Array Technology - S. Trimberger, Edr, 1994, Kluwer Academic
2. Digital Design Using Field Programmable Gate Array, P.K. Chan & S. Mourad, 1994, Prentice Hall
3. Field programmable gate array, S. Brown, R.J. Francis, J. Rose, Z.G. Vranesic, 2007, BS

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction**	
1.1	Digital system design options and tradeoffs	1
1.2	Design methodology and technology overview	2
1.3	High Level System Architecture and Specification: Behavioral modelling and simulation	2
1.4	Hardware description languages, combinational and sequential design	2
1.5	State machine design, synthesis issues, test benches.	2
2	**Programmable logic Devices**	
2.1	ROM, PLA, PAL, CPLD	3
2.2	FPGA Features, Limitations, Architectures and Programming.	2
2.3	Implementation of MSI circuits using Programmable logic Devices.	3
3	**FPGA architecture**	
3.1	FPGA Architectural options	1
3.2	Granularity of function and wiring resources, coarse V/s fine grained, vendor specific issues (emphasis on Xilinx and Altera)	3
3.3	Logic block architecture: FPGA logic cells, timing models, power dissipation	3
3.4	I/O block architecture: Input and Output cell characteristics, clock input, Timing, Power dissipation.	3
4	**Placement and Routing**	
4.1	Programmable interconnect - Partitioning and Placement	3
4.2	Routing resources, delays	3
4.3	Applications -Embedded system design using FPGAs, DSP using FPGAs	3
5	**Commercial FPGAs**	
5.1	Xilinx, Altera, Actel (Different series description only)	2
5.2	Case study Xilinx Virtex	4
5.3	Implementation of simple combinational and sequential circuits	3

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIFTH SEMESTER B.TECH DEGREE EXAMINATION, (**Model Question Paper)**

Course Code: ECT393

Program: Electronics and Communication Engineering

Course Name: FPGA Based System Design

Max.Marks: 100 Duration: 3Hours

PART A

Answer ALL Questions. Each Carries 3 mark.

1.	What are the synthesis issues in FPGA design.	K2
2	Describe FPGA design methodology.	K2
3	Differentiate PLA with PAL	K2
4	What are the limitations of FPGA.	K2
5	Compare coarse and fine grained FPGA architecture.	K2
6	What are the timing models in logic block architecture.	K2
7	List the applications of FPGA.	K2
8	Describe routing resources in FPGA routing.	K2
9	Describe how a combnational circuit can be mapped into Xilinx Virtex LUT.	K2
10	List different commercially available FPGAs.	K2

PART – B

Answer one question from each module; each question carries 14 marks.

Module – I

11. a)	Design a full adder using Verilog.	7	CO1	K3
11. b)	Explain behavioral modeling and simulation with an example.	7	CO1	K2
	OR			
12.a)	What is FSM? How it is used for FPGA.	7	CO1	K2
12.b)	Explain the purpose of test bench and how it is written in a HDL.	7	CO1	K2

Module – II

13 a)	Design the function F=XYZ’+Y’ Z+X Y’ using PLA	8	CO2	K3
13 b)	Compare CPLD with FPGA	6	CO2	K2
	OR			
14 a)	Implement the following Boolean function using PAL: F(w, x, y, z) = Σm (0, 2, 4, 10, 11, 12, 14, 15)m (0, 2, 4, 10, 11, 12, 14, 15)	8	CO2	K3
14 b)	Draw the structure of PAL and explain it.	6	CO2	K2

Module – III

15 a)	Draw and explain I/O block architecture of FPGA.	7	CO2	K2
15 b)	Draw and explain coarse grained FPGA architecture.	7	CO2	K2
	OR			
16 a)	Explain timing and power dissipation in Logic block and I/O block.	7	CO2	K2
16 b)	Draw and explain fine grained FPGA architecture.	7	CO2	K2

Module – IV

17 a)	Explain partitioning and placement processes in FPGA	8	CO4	K2
17 b)	Explain embedded system design using FPGAs	6	CO4	K2
	OR			
18 a)	Explain the delays associated with placement and routing	7	CO4	K2
18 b)	Explain DSP design using FPGAs	7	CO4	K2

Module – V

19 a)	With neat diagram explain the architecture of Xilinx Virtex IOB.	7	CO3	K2
19 b)	Design a four bit up counter with parallel load feature using Xilinx Virtex.	7	CO3	K3
	OR			
20 a)	Explain the mapping of combinational and sequential circuits using LUTs.	5	CO3	K3
20 b)	Explain the architecture of Xilinx Virtex CLB	9	CO3	K2

SEMESTER VI

HONOURS

ECT394	ELECTRONIC DESIGN AUTOMATION	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: The course aims to introduce principles behind advanced methods in automation of electronic design.

Prerequisites: Nil

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

CO 1	Apply Search Algorithms and Shortest Path Algorithms to find various graph solutions.
CO 2	Outline VLSI Design Flow and Design Styles and apply partitioning algorithms on graphs representing netlist.
CO 3	Illustrate Design Layout Rules and apply different algorithms for layout compaction.
CO 4	Make use of various algorithms to solve placement and floorplan problems.
CO 5	Utilise different algorithms to solve routing problems.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12
CO 1	3	2										3
CO 2	3	2										3
CO 3	3	2										3
CO 4	3	2										3
CO 5	3	2										3

Assessment Pattern

Bloom's Category		**Continuous Assessment Tests**		**End Semester Examination**
		1	**2**	
Remember				
Understand	K2	30	30	60
Apply	K3	20	20	40
Analyse				
Evaluate				
Create				

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

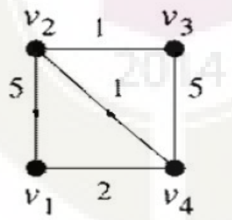
End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each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

CO Assessment Questions

CO1: Apply Search Algorithms and Shortest Path Algorithms to find various graph solutions

1.Represent the following graph by Adjacency Matrix.
2. List a DFS ordering of vertices for the graph shown in question 1 with starting node as H.
3. Perform topological sort on the graph in question1 and order the vertices with
Starting node is H.

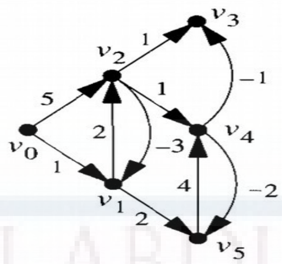
CO2: Outline VLSI Design Flow and Design Styles and apply partitioning algorithms on graphs representing netlist.



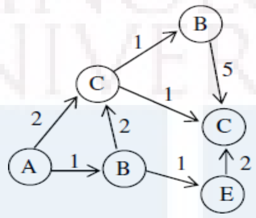
1.Perform KL partitioning on the above graph.You may assume any initial partition of your choice.
2. Draw the flowchart of VLSI Design Flow and explain the different stages

CO3: Illustrate Design Layout Rules and apply different algorithms for layout compaction.

1. For the following graph, find the longest path to all other vertices from vertex v_0, using Bellman-Ford Algorithm.

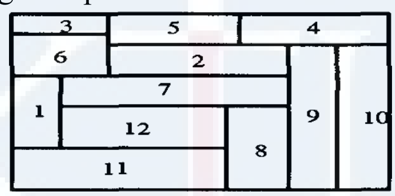


2. Use the Longest Path Algorithm to find the longest path from vertex A, in the following graph



CO4: Make use of various algorithms to solve placement and floorplan problems.

1. Consider the following floorplan.



Draw the floorplan slicing tree and the polar graphs of the above floorplan.

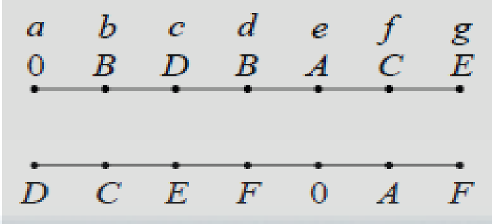
CO5: Utilise different algorithms to solve routing problems.

1.Perform LEE's Algorithm to find shortest path from S to T. Cells marked O indicate obstructions.

	T					
O			O	O	O	
		O				
			O	S		

2. Draw Horizontal and Vertical Constraint Graph for the following Channel Routing

3.



Model Question Paper

APJ Abdul Kalam Technological University

Sixth Semester B Tech Degree Examination

Branch: Electronics and Communication

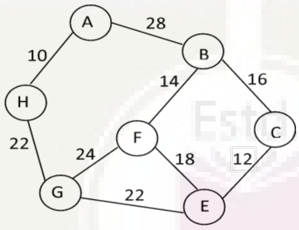
Course: ECT394 Electronic Design Automation

Time: 3 Hrs | Max. Marks: 100

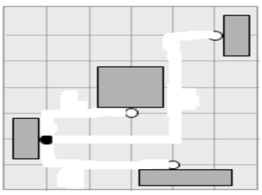
PART A

Answer All Questions

1. Define the following giving an example each (3) (K2)
   (a) Degree of a vertex (b) Subgraph (c) Directed Acyclic Graph (DAG)
2. Represent the following graph by Adjacency Matrix. (3) (K2)



3. Write short note on (a) Full Custom Design (b) Standard Cell Design (3) (K1)
4. Explain any three parameters based on which Partitioning is performed. (3) (K1)
5. What are the minimum distance rules in Design Rules for layout? (3) (K1)
6. Write inequality expressions for minimum distance and maximum distance constraints between two rectangular edges. (3) (K1)
7. For the following placement, calculate the wirelength by (a) Half Perimeter Method (b) Maximum Rectilinear Tree Method (3) (K3)



8. Represent the following floor ce Pair approach. (3) (K3)

9. How is Global Routing different from Detailed Routing? (3) (K1)
10. Define the following terms (a) Reserved Layer Model (b) Channel (c) Dogleg(3)(K1)

PART B

Answer one question from each module. Each question carries 14 marks.

11. (A) List a DFS ordering of vertices for the graph shown in question 2. (7) (K3)
Starting node is H.
(B) Perform topological sort on the graph and order the vertices. (7) (K3)
Starting node is H.

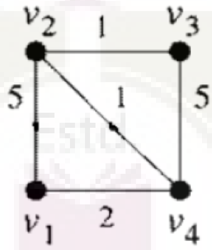
OR

12. (A) List a BFS ordering of vertices for the graph shown in question 2. (10)(K3)
Starting node is H.
(B) Give an application related to VLSI of BFS. (4) (K2)

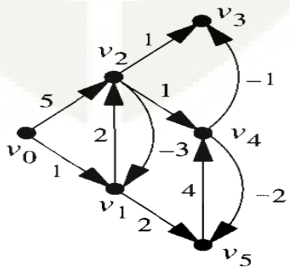
13. Draw the flowchart of VLSI Design Flow and explain the different stages. (14) (K1)

OR

14. Perform KL partitioning on the following graph. You may assume any initial (14)(K3)
partition of your choice.



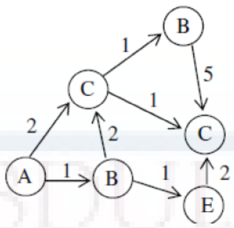
15. (A) For the following graph, find the longest path to all other vertices from (10) (K3)
vertex v_0, using Bellman-Ford Algorithm.



(B) What is the time complexity of Liao-Wong and Bellman-Ford Algorithms?(4) (K2)

OR

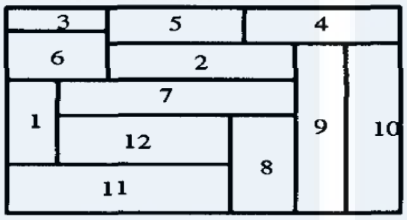
16. (A) Use the Longest Path Algorithm to find the longest path from vertex A, in the following graph. (8) (K3)



(B) What is the limitation of Longest Path Algorithm? (2) (K1)

(C) List two methods to find shortest path using Longest Path Algorithm (4) (K2)

17. Consider the following floorplan.



(A) Draw the floorplan slicing tree of the above floorplan. (6) (K3)

(B) Draw the polar graphs of above floorplan. (8) (K3)

OR

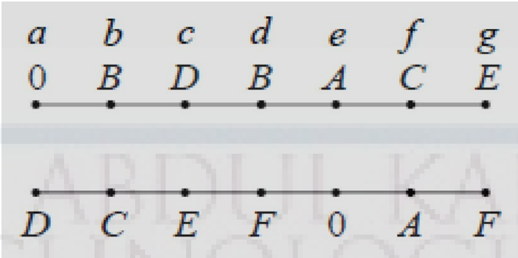
18. Given: Placement *P* with two fixed points *p*1 (100,175) and *p*2 (200,225), three free blocks *a*-*c* and four nets *N*1-*N*4. *N*1 (*P*1,*a*) *N*2 (*a*,*b*) *N*3 (*b*,*c*) *N*4 (*c*,*P*2). Find the coordinates of blocks (*xa*, *ya*), (*xb*, *yb*) and (*xc*, *yc*). (14) (K3)

19. Perform LEE's Algorithm to find shortest path from S to T. Cells marked O indicate obstructions. (14) (K3)

	T					
O			O	O	O	
		O				
			O	S		

OR

20. Draw Horizontal and Vertical Constraint Graph for the following Channel Routing. (14) (K3)



APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Simulation Assignments

1. Develop C code for all algorithms in Module 1, 2 and 3.
2. A digital circuit can be taken through all steps od VLSI Design Flow (ie. From HDL to Layout) using any standard tool set from Cadence, Synopsis or Mentor Graphics or similar tools

Syllabus

Module 1: Graph Terminology, Search Algorithms and Shortest Path Algorithms:

Graph Terminology: Basic graph theory terminology, Data structures for representation of
Graphs Search Algorithms: Breadth First Search, Depth First Search, Topological Sort
Shortest Path Algorithms: Dijkstra's Shortest-Path Algorithm for single pair shortest path, Floyd Warshall Algorithm for all pair shortest path

Module 2: Design Automation and Partitioning Algorithms:

Design Automation: VLSI Design Flow, VLSI Design Styles
Partitioning: Levels of Partitioning, Parameters for Partitioning, Classification of Partitioning Algorithms, Kernighan-Lin Algorithm, Fiduccia-Mattheyses Algorithm, Simulated Annealing

Module 3: Layout Compaction:

Layout: Layout Layers and Design Rules, Physical Design Optimizations
Compaction: Applications of Compaction, Informal Problem Formulation, Graph Theoretical Formulation, Maximum Distance Constraints, Longest Path algorithm for DAG, Longest path in graph with cycles, Liao-Wong Algorithm, Bellman-Ford Algorithm.

Module 4: Placement and Floorplanning:

Placement: Optimization Objectives, Wirelength Estimation, Weighted Wirelength, Maximum Cut Size, Wire Density
Placement Algorithms: Quadratic Placement
Floorplanning: Optimization Objectives, Slicing Floorplan, Non-Slicing Floorplan
Floorplan Representations: Constraint Graph, Sequence Pair
Floorplan Algorithms: Minimum Area Algorithm

Module 5: Global Routing and Detailed Routing:

Global Routing: Terminology and Definitions, Optimization Goals, Representation of Routing Regions
Maze Routing Algorithms: Lee's Algorithm, Hadlock Algorithm
Detailed Routing: Horizontal and Vertical Constraint Graph
Channel Routing Algorithms: Left-Edge algorithm

Text Books

1. Jin Hu, Jens Lienig, Igor L. Markov, Andrew B. Kahng, VLSI Physical Design: From Graph Partitioning to Timing Closure, Springer, 2011th edition.
2. Gerez,Sabih H., "Algorithms for VLSI Design Automation", John Wiley & Sons, 2006.
3. Sherwani, Naveed A., "Algorithms for VLSI Physical Design Automation", Kluwer Academic Publishers, 1999.

Reference Books

1. Sadiq M. Sait and H. Youssef, "VLSI Physical Design Automation: Theory and Practice", World Scientific, 1999.
2. Cormen, Thomas H., Charles E. Leiserson, and Ronald L. Rivest. "Introduction to Algorithms." The MIT Press, 3rd edition, 2009.

Course Contents and Lecture Schedule

No.	Topic	Number of Lectures
1	**Graph Terminology, Search Algorithms and Shortest Path Algorithms:**	
1.1	**Graph Terminology:** Basic graph theory terminology, Data structures for representation of Graphs	2
1.2	**Search Algorithms:** Breadth First Search, Depth First Search, Topological Sort	2
1.3	**Shortest Path Algorithms:** Dijkstra's Shortest-Path Algorithm for single pair shortest path, Floyd Warshall Algorithm for all pair shortest path	4
2	**Design Automation and Partitioning Algorithms:**	
2.1	**Design Automation:** VLSI Design Flow, VLSI Design Styles	3
2.2	**Partitioning:** Levels of Partitioning, Parameters for Partitioning, Classification of Partitioning Algorithms	1
2.3	Kernighan-Lin Algorithm, Fiduccia-Mattheyses Algorithm, Simulated Annealing	5
3	**Layout Compaction:**	

3.1	**Layout:** Layout Layers and Design Rules, Physical Design Optimizations	1
3.2	**Compaction:** Applications of Compaction, Informal Problem Formulation, Graph Theoretical Formulation, Maximum Distance Constraints	1
3.3	Longest Path algorithm for DAG, Longest path in graph with cycles, Liao-Wong Algorithm, Bellman-Ford Algorithm.	7
4	**Placement and Floorplanning:**	
4.1	**Placement:** Optimization Objectives, Wirelength Estimation, Weighted Wirelength, Maximum Cut Size, Wire Density	3
4.2	**Placement Algorithms:** Quadratic Placement	2
4.3	**Floorplanning:** Optimization Objectives, Slicing Floorplan, Non-Slicing Floorplan **Floorplan Representations:** Constraint Graph, Sequence Pair	3
4.4	**Floorplan Algorithms:** Minimum Area Algorithm	3
5	**Global Routing and Detailed Routing:**	
5.1	**Global Routing:** Terminology and Definitions, Optimization Goals, Representation of Routing Regions	1
5.2	**Maze Routing Algorithms:** Lee's Algorithm, Hadlock Algorithm	2
5.3	**Detailed Routing:** Horizontal and Vertical Constraint Graph	3
5.4	**Channel Routing Algorithms:** Left-Edge algorithm	2

ECT395	DETECTION AND ESTIMATION THEORY	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: This course aims to impart the fundamentals of detection and estimation theory in engineering applications

Prerequisite: MAT 101 Linear Algebra and Calculus
MAT 204 Probability, Random Process, and Numerical Methods
ECT 204 Signals and Systems

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

CO1 K2	Understand the fundamentals of statistical detection and estimation principles used in various engineering problems.
CO2 K3	Apply various types of statistical decision rules in engineering applications.
CO3 K3	Apply different types of estimation algorithms in engineering applications.

Mapping of course outcomes with program outcomes

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO11	PO12
CO 1	3	3										2
CO 2	3	3										2
CO 3	3	3										2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember			
Understand K2	30	30	60
Apply K3	20	20	40
Analyse			
Evaluate			
Create			

Mark distribution

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

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1): Understand the fundamentals of statistical detection and estimation principles used in various engineering problems. (K2)

1. Differentiate estimation and detection techniques.

2. Differentiate classical approach and bayesian approch in detection theory (or estimation).

3. Enumerate different applications which are using estimation and detection techniques.

4. Give the mathematical formulation of estimation and detection methods.

5. Draw receiver operating characteristics with all details

6. Give the significance of Bayes risk

7. How multiple hypothesis testing is done.

8. Give the significance of linear models in estimation and detection theory.

9. Significance of Cramer-Rao Lower Bound in estimation.

10. Differentiate MAP and ML methods in estimation (or detection).

Course Outcome 2 (CO2): Apply various types of statistical decision rules in engineering applications. (K3)

1. Describe Neyman-Pearson theorem (or Bayes risk or minimization of probability of error) and apply it to any binary hypothesis (eg. Signal in white Gaussian noise)

2. Derive/Obtain the matched filters for the detection of deterministic signals

3. Derive/Obtain the estimator-correlator for the detection of random signals

Course Outcome 3 (CO3): Apply different types of estimation algorithms in engineering applications. (K3)

1. Derive/Obtain the Minimum variance unbiased estimator (or best linear unbiased estimator) for any simple examples (eg. DC Signal in white Gaussian noise)
2. Derive/Obtain the Maximum likelihood estimator (or least squares estimator or minimum mean square error estimator) for any simple examples (eg. DC Signal in white Gaussian noise)
3. Using Bayesian approach, obtain an estimator for any simple examples.

SYLLABUS

Module 1 : Introduction to Detection and Estimation Theory

Fundamentals of detection theory, the mathematical detection problem. Fundamentals of estimation theory, the mathematical estimation problem. Review of Gaussian distribution. Application examples.

Module 2 : Statistical Detection Theory I

Hypothesis testing, classical approach, Neyman-Pearson theorem, likelihood ratio test, receiver operating characteristics, Bayesian approach, minimum probability of error, Bayes risk, multiple hypothesis testing.

Module 3 : Statistical Detection Theory II

Detection of deterministic signals, matched filters, detection of random signals, estimator-correlator, linear model, application examples.

Module 4 : Statistical Estimation Theory I

Minimum variance unbiased estimation, basics of Cramer-Rao Lower Bound, linear models, best linear unbiased estimation, application examples.

Module 5 : Statistical Estimation Theory II

Maximum likelihood estimation, least squares, Bayesian philosophy, minimum mean square error estimation, application examples.

Text Books

1. S.M. Kay, “Fundamentals of Statistical Signal Processing” Vol I: Estimation Theory, Pearson, 3/e, 2010.
2. S.M. Kay, “Fundamentals of Statistical Signal Processing” Vol II: Detection Theory, Pearson, 3/e, 2010.

Reference Books

1. H. L. Van Trees, “Detection, Estimation, and Modulation Theory”, Vol. I, John Wiley & Sons, 1968
2. Monson H. Hayes ,“Statistical Digital Signal Processing and Modelling" by, John Wiley & Sons, 2002.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction to Detection and Estimation Theory**	
1.1	Fundamentals of detection theory, review of probability and random variable	2
1.2	The mathematical detection problem	2
1.3	Fundamentals of estimation theory	1
1.4	The mathematical estimation problem	2
1.5	Review of Gaussian distribution. Application examples.	2
2	**Statistical Detection Theory I**	
2.1	Hypothesis testing	2
2.2	Classical approach, Neyman-Pearson theorem	2
2.3	Likelihood ratio test, Receiver operating characteristics	2
2.4	Bayesian approach, minimum probability of error, Bayes risk	2
2.5	Multiple hypothesis testing.	1
3	**Statistical Detection Theory II**	
3.1	Detection of deterministic signals	1
3.2	Matched filters	2
3.3	Detection of random signals	2
3.4	Estimator-correlator	2
3.5	Linear model, application examples.	2
4	**Statistical Estimation Theory I**	
4.1	Minimum variance unbiased estimation	2
4.2	Basics of Cramer-Rao Lower Bound	2
4.3	Linear models	2
4.4	Best linear unbiased estimation	2
4.5	Application examples	1
5	**Statistical Estimation Theory II**	
5.1	Maximum likelihood estimation	2
5.2	Least squares solution	2
5.3	Bayesian philosophy	2
5.4	Minimum mean square error estimation	2
5.5	Application examples	1

Simulation Assignments (using MATLAB or Python)

1. Generate and familiarize PDF and CDF of Normal distribution.
2. Generate DC level in White Gaussian Noise.
3. Simulate a Neyman-Pearson Detector.
4. Simulate a Maximum Likelihood Estimator.
5. Simulate a Best Linear Unbiased Estimator.

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY FIFTH SEMESTER B.TECH DEGREE EXAMINATION

ECT 395 - Detection and Estimation Theory

Max. Marks: 100 Duration: 3 hrs

PART A

*(Answer **all** questions. Each question carries 3 marks each).*

1. Enumerate different applications which are using estimation and detection techniques. (3)
2. Differentiate estimation and detection techniques. (3)
3. Differentiate classical approach and bayesian approch in detection theory. (3)
4. Give the mathematical formulation of detection methods. (3)
5. Draw receiver operating characteristics with all details (3)
6. Give the significance of Bayes risk (3)
7. Give the significance of linear models in estimation theory. (3)
8. Significance of Cramer-Rao Lower Bound in estimation. (3)
9. What is Minimum Variance Unbiased Estimation? (3)
10. Differentiate MAP and ML methods in estimation. (3)

PART B

*(Answer any **one** question from each module. Each question carries 14 marks each.)*

Note:

(1) Notation $x \sim \mathrm{N}(\mu, \sigma^2)$ denotes x is normally distributed with mean μ and variance σ^2.

(2)Also, bold small letters indicate vectors and bold capital letters indicate matrices.

11. Obtain the mathematical formulation of estimation method with an example. (14)

OR

12 Using radar system as an example, differentiate estimation and detection techniques. (14)

.

13. Design Neyman-Pearson detector for the unknown level A in White Gaussian Noise with variance σ^2. (14)

OR

14. Describe the Bayesian approaches in the design of detectors. (14)

15. Obtain Matched Filter detector for N-sample deterministic signal in noise, $w[n] \sim N(0, \sigma_n^2)$ where $w[n]$'s are uncorrelated. (14)

OR

16. Describe estimator-correlator in the detection of random signals. (14)

17. Consider the multiple observations (14)

$$x[n] = A + w[n]; \quad n = 0, 1, \ldots, N-1$$

where $w[n] \sim N(0, \sigma^2)$. Determine CRLB for A?

OR

18. Derive the Best Linear Unbiased Estimator for the multiple observations (14)

$$x[n] = A + w[n]; \quad n = 0, 1, \ldots, N-1$$

where A is an unknown level to be estimated and $w[n]$ is White Noise with unspecified PDF and variance σ^2.

19. Derive the Maximum Likelihood Estimator for the multiple observations (14)

$$x[n] = A + w[n]; \quad n = 0, 1, \ldots, N-1$$

where A is an unknown level to be estimated and $w[n]$ is White Gaussian Noise with known variance σ^2.

OR

20. Prove that the optimal estimator which minimizes the Bayesian Mean Square Error is the mean of the posterior PDF.

(14)

ECT396	MIMO AND MULTIUSER COMMUNICATION SYSTEMS	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: MIMO systems are rising attention of the academic community and industry because of their potential to increase to capacity and diversity gain proportionally with the number of antennas. OFDM is a promising solution to mitigate the effect of inter symbol interference (ISI) and multipath fading. MIMO OFDM is an attractive air interface solution for multiuser communication and effectively deployed in wireless local area networks, fifth Generation (5G) wireless cellular standards.

Prerequisite: MAT 204 Probability and Random Process, ECT 305 Analog and Digital Communication.

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

CO 1	Describe digital communication over multipath channels
CO 2	Analyse the performance of multiuser communication techniques over generalized fading channel.
CO 3	Describe the concept of MIMO systems and determine the capacity of MIMO channel
CO 4	Introduce OFDM and associated timing and frequency synchronization in MIMO receiver
CO 5	To explain the theory of MIMO multiuser communication systems.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand K2	30	30	60
Apply K3	20	20	40
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1)

1. Define doppler spread.
2. Distinguish between flat fading and frequency selective fading
3. Derive the relation between Power spectra and channel correlation.

Course Outcome 2 (CO2)

1. State and infer the capacity of different multiple access techniques.
2. Describe CDMA signal and channel model.
3. Derive the autocorrelation matrix of CDMA multiuser Asynchronous transmission.

Course Outcome 3 (CO3)

1. Determine the channel capacity of SISO and MIMO systems.
2. Determine the channel capacity of MIMO system when CSI is known to the transmitter side.
3. Compare the detection performance of MLSE and ZF equalizer.

Course Outcome 4 (CO4)

1. Describe FFT based implementation of OFDM.
2. Analyze the effect of symbol time offset in OFDM systems.
3. Describe the synchronization using cyclic prefix to OFDM systems.

Course Outcome 5 (CO5)

1. Distinguish between array gain and diversity gain.
2. Define spatial multiplexing.
3. Draw the general block diagram of MIMO system.
4. Write the motivation behind using multiuser communication in wireless scenario.

MODEL QUESTION PAPER

APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY MODEL QUESTION PAPER

ECT396 MIMO AND MULIUSER COMMUNICATION SYSTEMS

Time: 3 hours **Max.Marks:100**

PARTA

Answer ***all*** questions. Each question carries ***3marks***.

1. Distinguish between frequency selective and frequency non selective fading.
2. Define Doppler spread.
3. State the capacity of FDMA
4. Mention the applications of TDMA and CDMA
5. Draw the channel model for SIMO system.
6. Explain the significance of Ergodic capacity.
7. What are the gains available in MIMO systems?
8. Define spatial multiplexing.
9. Define inter symbol interference.
10. Write short notes on OFDMA.

PARTB

Answer ***anyone*** question from each module. Each question carries ***14marks.***

MODULE I

11. (a) Draw and explain the Tapped delay line channel model used in frequency selective slowly fading channel . (10 marks)
    (b) Distinguish between fast and slow fading. (4 marks)

12. A multipath fading channel has a multipath spread of 1s and a Doppler spread of 0.01 Hz. The total channel bandwidth at band pass available for signal transmission is 10 Hz. To mitigate the effect of ISI select the pulse duration 10s.
    (a) Calculate the coherence bandwidth and coherence time. (5 marks)
    (b) Is the channel is frequency selective or not? Justify your answer. (5 marks)
    (c) Is the channel fading slowly or rapidly? Justify your answer. (4 marks)

MODULE II

13. (a) Briefly describe FDMA and TDMA. (8 marks)
    (b) State and infer the capacity of single user CDMA detection scheme. (6 marks)

14. (a) With the aid of Gaussian PDF derive the Maximum Likelihood (ML) criteria of CDMA decorrelation receiver. (10 marks)

MODULE II

15. (a) Determine the channel capacity of MIMO system when CSI is known to the transmitter side and when CSI is not available at transmitter side. (10 marks)
    (b) Distinguish between outage probability and outage capacity. (4 marks)
16. (a) State the significance of Ergodic capacity. (5 marks)
    (b) Determine the capacity of deterministic MIMO channel assuming AWGN capacity. (9 marks)

MODULE IV

17. (a) What is sphere decoding? (4 marks)
    (b) Compare the detection performance of ZF and MMSE signal detection techniques in MIMO receiver. (10 marks)
18. (a) Compare array gain and diversity gain. (4 marks)
    (b) Briefly describe receive and transmit antenna diversity. (10 marks)

MODULE V

19. (a) Consider a transmitter sends digital information by use of Msignal waveforms $\{s_m(t), m = 1,2,...., M\}$ over an AWGN channel. The channel is assumed to be corrupt the signal by the addition of white Gaussian noise. Write down the expression for received signal in the interval $0 \leq t \leq T$and draw the model for received signal passed through the channel. (4 marks)
    (b) Describe the FFT based implementation of OFDM system. (10 marks)
20. (a) State and prove Nyquist condition for zero ISI. (4 marks)
    (b) Describe the synchronization technique using cyclic prefix in OFDM systems. (10 marks)

SYLLABUS

Module 1 – Digital Communication over Fading Multipath Channels

Multipath fading, Coherence time, Coherence bandwidth, Doppler spread, Characterization of fading multipath channels, Statistical model for fading channels (Rayleigh and Rice distribution), Relation between channel correlation and Power spectral density, Signal characteristics on the choice of channel model (frequency selective and frequency nonselective fading), Frequency nonselective slowly fading channel, Frequency selective slowly fading channel, Fast fading, Rake receiver.

Module 2 – Multiuser Communications

Types of multiple access techniques (FDMA,TDMA and CDMA), Capacity of multiple access methods (*Inference only*). Single user detection, Multiuser detection, CDMA signal and channel model, CDMA optimum receiver (Synchronous transmission, Asynchronous transmission), Suboptimum detectors (Single user detector and Decorrelation receiver). Practical applications of multiple access techniques.

Module 3 – MIMO System

Signal and channel model for SISO,SIMO,MISO and MIMO, Capacity of frequency flat deterministic MIMO channel (both channel unknown and known to the transmitter), SIMO channel capacity, MISO channel capacity, Capacity of random MIMO channels, Ergodic capacity, Outage capacity, Capacity of frequency selective MIMO channels (both channel unknown and known to the transmitter)

Module 4 – Diversity and Receiver

Array gain, Diversity gain, Spatial multiplexing, Receive antenna diversity, Transmit antenna diversity, SISO receiver (MLSE, ZF and Decision feedback equalizer), SIMO receiver, MIMO receiver (both Optimal and suboptimal), Sphere decoding.

Module 5 – OFDM

Review of AWGN channel and band limited ISI channel, Introduction to multicarrier systems, FFT based multicarrier system, Mitigation of subcarrier fading, SISO-OFDM, MIMO-OFDM, Coarse time synchronization, Fine time synchronization, Coarse frequency synchronization, OFDMA, Wireless standards (WiMAX, and 3GPP LTE)

Note: Mathematical model and analysis to be covered for the entire topic.

Text Books

1. "Digital Communications", John G Proakis, 4/e, McGraw-Hill.
2. "Fundamentals of Wireless Communications", David Tse and Pramod Viswanath, Cambridge University Press, 2005.
3. "Introduction to Space Time Wireless Communications", A Paulraj, Nabar and D Gore Cambridge University Press, 2003.
4. "MIMO OFDM Wireless Communications with MATLAB", Y S Cho, J Kim, Won Yong Yang, Chung G Kang, John Wiley& sons private Ltd, 2010.

Reference Books

5. "Space Time Block Coding for Wireless Communications", Erik G Larsson, Cambrdige University Press, 2003.

6. "MIMO Wireless Communications", E Biglieri, R Calderbank, A Constantinides, A Goldsmith, A Paulraj, Cambridge University Press.
7. "Digital Communications", Simon Haykin, John Wiley & Sons Pvt Ltd. 2001.
   "Wireless Communications" Andrea Goldsmith, Cambridge University Press 2005

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Digital Communication over Fading Multipath Channels**	
1.1	Multipath fading, Coherence time, Coherence bandwidth, Doppler spread	1
1.2	Characterization of fading multipath channels, Statistical model for fading channels (Rayleigh and Rice distribution), Relation between channel correlation and Power spectral density	4
1.3	Signal characteristics on the choice of channel model (frequency selective and frequency nonselective fading), Frequency nonselective slowly fading channel, Frequency selective slowly fading channel	3
1.4	Fast fading, Rake receiver	2
2	**Multiuser Communications**	
2.1	Types of multiple access techniques (FDMA,TDMA and CDMA), Capacity of multiple access methods (without proof, Inference only).	2
2.2	Single user detection, Multiuser detection	1
2.3	CDMA signal and channel model, CDMA optimum receiver (Synchronous transmission, Asynchronous transmission),	2
2.4	Suboptimum detectors (Single user detector and Decorrelation receiver).	1
2.5	Practical applications of multiple access techniques.	1
3	**MIMO System**	
3.1	Signal and channel model for SISO, SIMO, MISO and MIMO	2
3.2	Capacity of frequency flat deterministic MIMO channel (both channel unknown and known to the transmitter), SIMO channel capacity, MISO channel capacity	4
3.3	Capacity of random MIMO channels	1
3.4	Ergodic capacity, Outage capacity, Capacity of frequency selective MIMO channels (both channel unknown and known to the transmitter)	2
4	**Diversity and Receiver**	
4.1	Array gain, Diversity gain, Spatial multiplexing.	1
4.2	Receive antenna diversity, Transmit antenna diversity	1
4.3	SISO receiver (MLSE, ZF and Decision feedback equalizer)	2
4.4	SIMO receiver	1
4.5	MIMO receiver (both Optimal and suboptimal), Sphere decoding.	3
5	**OFDM**	
5.1	Review of AWGN channel and band limited ISI channel	1
5.2	Introduction to multicarrier systems, FFT based multicarrier system	2

5.3	Mitigation of subcarrier fading, SISO-OFDM, MIMO-OFDM	2
5.4	Coarse time synchronization, Fine time synchronization, Coarse frequency synchronization	3
5.5	OFDMA, Wireless standards (WiMAX, and 3GPP LTE)	2

SIMULATION ASSIGNMENTS

The following simulation assignments can be done with Python/ MATLAB/ SCILAB /LabVIEW

1 Frequency Non-selective Slowly Fading Channel

- Generate binary PSK and binary FSK signals for transmission over a frequency non-selective slowly fading channel.
- Obtain the received equivalent lowpass signal of the transmitted signal using equation 13.3-1. Also plot the BER-SNR curve for coherent binary PSK and FSK detector using equations 13.3-2 and 13.3-3 respectively in page 846 in *Digital Communications by John G Proakis, 4/e*, for fixed attenuation value, α fixed and follows Rayleigh distribution case.
- Plot the BER-SNR curve for coherent binary PSK and FSK detector using equations 13.3-13 in page 848 in *Digital Communications by John G Proakis, 4/e* for α followingRayleigh distribution.
- Compare the BER-SNR curve for AWGN and Rayleigh fading channel.

2 CDMA Transmitter and Receiver

- Create 2 random binary sequence of 100 bit each as data blocks of 2 users.
- Generate the composite transmitted signal, s(t) for 3 users using equations 16.3-7 in page 1037 in *Digital Communications by John G Proakis, 4/e.*
- Add AWGN of different variances to generate the received signal, r(t).
- Realize the optimum multiuser receiver for synchronous transmission shown in Fig. 16.3-1 in page 1040 in *Digital Communications by John G Proakis, 4/e*
- Observe the decoded bits for AWGN of different variances.

3 Capacity of MIMO Channels

- Create MIMO channel transfer matrix, H of size M_R x M_T, where M_R and M_T represents number of receive and transmit antennas respectively.
- Compute the capacity of SISO, SIMO, MISO and MIMO channels for different values of SNR using equations in page 138 in *Introduction to Space Time Wireless Communications by A Paulraj, Nabar and D Gore.*

- Plot Capacity-SNR curve for different channels and compare.

4 Performance of SISO Receiver

- Realize the signal model for SISO frequency selective fading channel given in equation 7.5 in page 138 in *Introduction to Space Time Wireless Communications by A Paulraj, Nabar and D Gore.*
- Transmit a sequence of symbols based on signal model.
- Obtain the estimated symbol sequence using MLSE receiver based on equation 7.8 in page 139 in *Introduction to Space Time Wireless Communications by A Paulraj, Nabar and D Gore.*

5 OFDM Communication System

- Realize the block diagram of OFDM communication system shown in Fig 11.2-4 in page 750 in *Digital Communications by John G Proakis, 4/e.*
- Create a random bit vector of arbitrary length. Realize the OFDM transmitter by mapping the message bits into a sequence of QAM symbols and convert it into N parallel streams.
- Each of N symbols from serial-to-parallel (S/P) conversion is carried out by the different subcarrier. Realize the multicarrier modulation by computing IFFT.
- Add cyclic prefix, realize parallel to serial converter and DAC to generate the transmitted signal.

Transmit the signal through a fading channel.

- Realize OFDM receiver by first removing cyclic prefix followed by serial to parallel conversion, FFT computation, signal detection and parallel to serial conversion.
- Plot the BER-SNR curve and analyse.

ECT397	COMPUTATIONAL TOOLS FOR SIGNAL PROCESSING	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: This course aims to use the computational tools in signal processing to solve industry problems.

Prerequisite: ECL201 Scientific Computing Lab, ECT204 Signals and Systems, ECT303 Digital Signal Processing

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

CO 1	Compute posterior probability using pymc3 for practical applications
CO 2	Compute linear and logistic regression with pymc3
CO 3	Perform Bayesian analysis for practical applications.
CO 4	Implement Kalman filters
CO 5	Implement partcle fillters for practical applications

Mapping of course outcomes with program outcomes

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3			3							2
CO 2	3	3	2	3	3							2
CO 3	3	3	2	3	3	2						2
CO 4	3	3	2	3	3	2						2
CO 5	3	3	2	3	3	2						2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember	10	10	20
Understand	30	30	60
Apply	10	10	20
Analyse			
Evaluate			
Create			

Mark distribution

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

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1): Computing posterior probability with pymc3
1. Write Python code to compute the posterior distribution of a 10X10 Gaussian random data set.
2. Write Python functio to compute the autocorrelation of a 5X5 unform random data.

Course Outcome 2 (CO2): Compute linear and logistic regression with pymc3
1. Write a python code to design a regression model by coding setosa =0, versicolor =1, and virginica = 2 in IRIS data set.?
2. Write a python code usig pymc3 to estimate regression parameters using a simple linear model y~ax+b, where y is Normally distributed with mean ax+b and variance σ2

Course Outcome 3 (CO3): Perform Bayesian analysis for practical applications.
1. Write a python code using pymc3 to compute the bayes factor for the coin toss using a uniform prior beta(1,1) . Set p(heads)=0.5
2. Write a python code using pymc3 to implement a bauesian regression model with intercept1 and slope 3.Use posterior predictive checks to validate the model

Course Outcome 4 (CO4): Implement Kalman filters.
1. Write a python code to predict a random walk using discrete Bayes filter
2. Write a python code to track the movement of an accelerating aircraft using Kalman filter

Course Outcome 5 (CO5): Implement partcle fillters for practical applications
1. Write a python code using pymc3 to create a model that specifies the posterior probability of human sleeping pattern as a function of time using MCMC method.
2. Write a python code to track a robotic movement using Particle Filter

SYLLABUS

Module 1 Probabilistic Programming
Statistical Modelling using pymc3, Probability concepts, Bayes theorem, Bayesian Statistics and modelling, Modelling Coin flipping as Bayesian, Choosing the likelihood and prior, Posterior computation, Posterior predictive analysis, Posterior plots. Likelihood theory and Estimation

Module 2 Modelling Linear and Logistic Regression
Modelling Linear Regression, Polynomial Regression, Multiple Linear Regression,Logistic Regression, Poisson Regression using pymc3

Module 3 Bayesian Modelling

Bayesian analysis using pymc3, Posterior predictive checks, Model specifications using pymc3,Examples of Bayesian Analytics. Bayes factor, Sequential Monte carlo to compute Bayes factors, Recursive state estimation, Modeling functions using pymc3, Covariance functions and kernels, Bayesian Regression Models

Module 4 GH and Kalman Filter

GH filter, Choosing G and H factors, Simple simulation models using GH filters, Discrete Bayes Filter for predicting the random movement, Recursive estimation and prediction, Effect of noisy environment. Kalman filter- updation using measurements and observations, Kalman Gain calculation and Prediction, Process noise and Measurement noise. Kalman Filter Equations implementation in python.

Module 5 Particle Filter

Multivariate Kalman Filter-Modelling and Designing, Effect of Nonlinearity, Nonlinear Filters, Smoothing, Adaptive Filtering. Markov concepts, Monte carlo integration, Basics of Markov chain Monte Carlo, Implementation using filterpy module.Particle Filter algorithm and Implementation.

Textbooks and References

1. "Bayesian Analysis with python", Osvaldo Martin, PACKT Open Source Publishing
2. "Machine Learning: A Bayesian and Optimization Perspective",Sergios Theodoridis, Academic Press.
3. https://github.com/rlabbe/Kalman-and-Bayesian-Filters-in-Python
4. http://140.113.144.123/EnD108/Bayesian%20filtering-%20from%20Kalman%20filters%20to%20Particle%20filters%20and%20beyond.pdf
5. "Ipython Interactive Computing and Visualization Cookbook", Cyrille Rossant , PACKT Open Source Publishing
6. "Bayesian Signal Processing: Classical, Modern, and Particle Filtering Methods", James V. Candy, Wiley-IEEE Press

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Probabilistic Programming**	
1.1	Statistical Modelling using pymc3, Probability concepts	2
1.2	Bayes theorem, Bayesian Statistics and modelling	2
1.3	Modelling Coin flipping as Bayesian, Choosing the likelihood and prior, Posterior computation,	2
1.4	Posterior predictive analysis, Posterior plots. Likelihood theory and Estimation	3
2	**Modelling Linear and Logistic Regression**	
2.1	Modelling Linear Regression	2
2.2	Polynomial Regression, Multiple Linear Regression	2
2.3	Logistic Regression, Poisson Regression using pymc3	4

3	**Bayesian Modelling**	
3.1	Bayesian analysis using pymc3, Posterior predictive checks, Model specifications using pymc3,Examples of Bayesian Analytics.	3
3.1	Bayes factor, Sequential Monte carlo to compute Bayes factors, Recursive state estimation, Modeling functions using pymc3, Covariance functions and kernels.	3
3.3	Bayesian Regression Models.	2
4	**GH and Kalman Filter**	
4.1	GH filter, Choosing G and H factors, Simple simulation models using GH filters.	2
4.2	Discrete Bayes Filter for predicting the random movement, Recursive estimation and prediction, Effect of noisy environment.	2
4.3	Kalman filter- updation using measurements and observations, Kalman Gain calculation and Prediction, Process noise and Measurement noise. Kalman Filter Equations implementation in python.	4
5	**Particle Filter**	
5.1	Multivariate Kalman Filter - Modelling and Designing	2
5.2	Effect of Nonlinearity, Nonlinear Filters, Smoothing, Adaptive Filtering.	2
5.3	Markov concepts, Monte carlo integration, Basics of Markov chain Monte Carlo	2
5.4	Implementation using filterpy module. Particle Filter algorithm and Implementation.	4

Simulation Assignments

1. Create a noisy measurement system. Design a g-h filter to filter out the noise and plot it. Write a code to filter 100 data points that starts at 5, has a derivative of 2, a noise scaling factor of 10, and uses g=0.2 and h=0.02. Set your initial guess for x to be 100.

2. Design a filter to track the position of a train. Its position is expressed as its position on the track in relation to some fixed point which we say is 0 km. I.e., a position of 1 means that the train is 1 km away from the fixed point. Velocity is expressed as meters per second. Measurement of position is doeonce per second, and the error is ± 500 meters.The train is currently at 23 kilometer, moving at 15 m/s,accelerating at 0.2 m/secˆ2. Plot the results.

3. Using Discrete Bayes Filter, predict the movemet of a dog. The current position of the dog is 17 m. The epoch is 2 seconds long, and the dog is traveling at 15 m/s. Where will the dog be in two seconds?

4. Compute the statistics of a Gaussian function using filterpy() module

5. Design a Kalman filter to track the movement of a dog(parameters same as previous one) in a Noisy environment

6. Prove that the binomial and beta distributions are conjugate pairs with respect to the mean value.
7. Show that the conjugate prior of the multivariate Gaussian with respect to the precision matrix, Q, is a Wishart distribution.

8. Prove that if a probability distribution p satisfies the Markov condition, as implied by a BN, hen p is given as the product of the conditional distributions given the values of the parents.

9. Suppose that n balls are thrown independently and uniformly at random into n bins.

   (a) Find the conditional probability that bin 1 has one ball given that exactly one ball fell into the irst three bins.
   (b) Find the conditional expectation of the number of balls in bin 1 under the condition that bin 2 received no balls.
   (c) Write an expression for the probability that bin 1 receives more balls than bin 2.

Model Question Paper

A P J Abdul Kalam Technological University

Fifth Semester B Tech Degree Examination

Course: ECT 397 Computational Tools for Signal Processing

Time: 3 Hrs **Max. Marks:100**

PART A

Answer All Questions

1	State Bayes theorem and explain the significance of the terms prior, likelihood and posterior.	(3)	K_2
2	Write Python code with pymc3 to realize a Bernoulli trial with $p(head) = 0.4$	(3)	K_3
3	Compare logistic and linear regression	(3)	K_2
4	Explain the concept of Poisson regression and logistic regression?	(3)	K_2
5	Write the significance of choosing conjugate priors in Bayesian analysis	(3)	K_2
6	Explain Schwarz Criterion.	(3)	K_1
7	Compare process noise and measurement noise in Kalman Filter.	(3)	K_2
8	Write the algorithm for GH filter design	(3)	K_3
9	Write a python code to compute relative error in the true value of π	(3)	K_3
10	Compare Nonlinear and Linear filters	(3)	K_2

PART B

Answer one question from each module. Each question carries 14 mark.

Module I

11(A)	Assume that you have a dataset with 100 data points of Gaussian distribution with a mean of 13 and standard deviation of 1.5. Using PyMC3, write Python code to compute: • The posterior distribution • The prior distribution • The posterior predictive distribution .	(8)	K_3
11(B)	Write a python code to find the Bayesian credible interval in the above question. How is it different from confidence interval.	(6)	K_3

OR

12(A)	Write a python code to evaluate the statistical correlation between variables in a 5 × 5 Gaussian random dataset.	(8)	K_3
12(B)	Show that $N(x \mid \mu, \Sigma)$ for known Σ is of an exponential form and that its conjugate prior is also Gaussian.	(6)	K_2

Module II

13(A)	Consider the linear model $y \; ax + b$ sampled from a probability distribution $y \; N(ax + b, \sigma^2)$. Use pymc3, write a python code to estimate the parameters a,b and σ.	(8)	K_3
13(B)	Assume that x_n, $n = 1, 2, \ldots, N$, are iid observations from a Gaussian distribution $N(\mu, \sigma^2)$. Obtain the MAP estimate of μ, if the prior follows the exponential distribution $p(\mu) = \lambda \exp(-\lambda\mu)$, $\lambda > 0$, $\mu >= 0$,	(6)	K_2

OR

14(A)	Write a python code to generate random dataset using a noisy linear process with intercept1 , slope 2 and noise variance of 0.5. Simulate 100 data points and write a code to fit a linear regression to the data	(8)	K_3
14(B)	Write the steps involved in multiple linear regression technique	(6)	K_2

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Module III

15(A)	Write a python code to estimate the mean and standard deviation of a randomly generated gaussian data using SMC method in pymc3	(8)	K_3
15(B)	Explain how posterior predictive checks are used in validating a model using pymc3	(6)	K_2

OR

16(A)	Consider the linear model $y = \alpha + \beta * x$ sampled from a probability distribution $y \sim N(\alpha + \beta * x, \varepsilon)$. Use pymc3, write a python code to estimate the best values of α, β using Bayesian Linear Regression model. .	(8)	K_3
16(B)	Explain the steps involved in calculating Bayes factor in pymc3	(6)	K_2

Module IV

17(A)	Design an algorithm using Kalman filter to track a constant velocity aircraft in one dimension.	(8)	K_3
17(B)	Give a brief idea about recursive estimation technique.	(6)	K_2

OR

18(A)	Design an algorithm using Kalman filter to track an accelerating aircraft in one dimension.	(8)	K_3
18(B)	Explain the concept of Kalman filter gain factor.	(6)	K_2

Module V

19(A)	Describe the essential steps in the derivation of the Particle filter.	(8)	K_2
19(B)	Explain Sequntial Importance sampling algorithm?	(6)	K_2

OR

20(A)	Explain Multivariate Kalman Filter algorithm.	(8)	K_2
20(B)	Explain different resampling algorithms used in designing particle filter	(6)	K_2

ECT398	DETECTION AND ESTIMATION THEORY	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: This course aims to impart the fundamentals of detection and estimation theory in engineering applications

Prerequisite: MAT 101 Linear Algebra and Calculus
MAT 204 Probability, Random Process, and Numerical Methods
ECT 204 Signals and Systems

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

CO1 K2	Understand the fundamentals of statistical detection and estimation principles used in various engineering problems.
CO2 K3	Apply various types of statistical decision rules in engineering applications.
CO3 K3	Apply different types of estimation algorithms in engineering applications.

Mapping of course outcomes with program outcomes

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO11	PO12
CO 1	3	3										2
CO 2	3	3										2
CO 3	3	3										2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand K2	30	30	60
Apply K3	20	20	40
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1): Understand the fundamentals of statistical detection and estimation principles used in various engineering problems. (K2)

1. Differentiate estimation and detection techniques.
2. Differentiate classical approach and bayesian approch in detection theory (or estimation).
3. Enumerate different applications which are using estimation and detection techniques.
4. Give the mathematical formulation of estimation and detection methods.
5. Draw receiver operating characteristics with all details
6. Give the significance of Bayes risk
7. How multiple hypothesis testing is done.
8. Give the significance of linear models in estimation and detection theory.
9. Significance of Cramer-Rao Lower Bound in estimation.
10. Differentiate MAP and ML methods in estimation (or detection).

Course Outcome 2 (CO2): Apply various types of statistical decision rules in engineering applications. (K3)

1. Describe Neyman-Pearson theorem (or Bayes risk or minimization of probability of error) and apply it to any binary hypothesis (eg. Signal in white Gaussian noise)
2. Derive/Obtain the matched filters for the detection of deterministic signals
3. Derive/Obtain the estimator-correlator for the detection of random signals

Course Outcome 3 (CO3): Apply different types of estimation algorithms in engineering applications. (K3)

1. Derive/Obtain the Minimum variance unbiased estimator (or best linear unbiased estimator) for any simple examples (eg. DC Signal in white Gaussian noise)
2. Derive/Obtain the Maximum likelihood estimator (or least squares estimator or minimum mean square error estimator) for any simple examples (eg. DC Signal in white Gaussian noise)
3. Using Bayesian approach, obtain an estimator for any simple examples.

SYLLABUS

Module 1 : Introduction to Detection and Estimation Theory

Fundamentals of detection theory, the mathematical detection problem. Fundamentals of estimation theory, the mathematical estimation problem. Review of Gaussian distribution. Application examples.

Module 2 : Statistical Detection Theory I

Hypothesis testing, classical approach, Neyman-Pearson theorem, likelihood ratio test, receiver operating characteristics, Bayesian approach, minimum probability of error, Bayes risk, multiple hypothesis testing.

Module 3 : Statistical Detection Theory II

Detection of deterministic signals, matched filters, detection of random signals, estimator-correlator, linear model, application examples.

Module 4 : Statistical Estimation Theory I

Minimum variance unbiased estimation, basics of Cramer-Rao Lower Bound, linear models, best linear unbiased estimation, application examples.

Module 5 : Statistical Estimation Theory II

Maximum likelihood estimation, least squares, Bayesian philosophy, minimum mean square error estimation, application examples.

Text Books

1. S.M. Kay, "Fundamentals of Statistical Signal Processing" Vol I: Estimation Theory, Pearson, 3/e, 2010.

2. S.M. Kay, "Fundamentals of Statistical Signal Processing" Vol II: Detection Theory, Pearson, 3/e, 2010.

Reference Books

1. H. L. Van Trees, "Detection, Estimation, and Modulation Theory", Vol. I, John Wiley & Sons, 1968

2. Monson H. Hayes ,"Statistical Digital Signal Processing and Modelling" by, John Wiley & Sons, 2002.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction to Detection and Estimation Theory**	
1.1	Fundamentals of detection theory, review of probability and random variable	2
1.2	The mathematical detection problem	2
1.3	Fundamentals of estimation theory	1
1.4	The mathematical estimation problem	2
1.5	Review of Gaussian distribution. Application examples.	2
2	**Statistical Detection Theory I**	
2.1	Hypothesis testing	2
2.2	Classical approach, Neyman-Pearson theorem	2
2.3	Likelihood ratio test, Receiver operating characteristics	2
2.4	Bayesian approach, minimum probability of error, Bayes risk	2
2.5	Multiple hypothesis testing.	1
3	**Statistical Detection Theory II**	
3.1	Detection of deterministic signals	1
3.2	Matched filters	2
3.3	Detection of random signals	2
3.4	Estimator-correlator	2
3.5	Linear model, application examples.	2
4	**Statistical Estimation Theory I**	
4.1	Minimum variance unbiased estimation	2
4.2	Basics of Cramer-Rao Lower Bound	2
4.3	Linear models	2
4.4	Best linear unbiased estimation	2
4.5	Application examples	1
5	**Statistical Estimation Theory II**	
5.1	Maximum likelihood estimation	2
5.2	Least squares solution	2
5.3	Bayesian philosophy	2
5.4	Minimum mean square error estimation	2
5.5	Application examples	1

Simulation Assignments (using MATLAB or Python)

1. Generate and familiarize PDF and CDF of Normal distribution.

2. Generate DC level in White Gaussian Noise.

3. Simulate a Neyman-Pearson Detector.

4. Simulate a Maximum Likelihood Estimator.

5. Simulate a Best Linear Unbiased Estimator.

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SIXTH SEMESTER B.TECH DEGREE EXAMINATION

Max. Marks: 100 **ECT 398- Detection and Estimation Theory** Duration: 3 hrs

PART A

*(Answer **all** questions. Each question carries 3 marks each).*

1. Enumerate different applications which are using estimation and detection techniques. (3)
2. Differentiate estimation and detection techniques. (3)
3. Differentiate classical approach and bayesian approch in detection theory. (3)
4. Give the mathematical formulation of detection methods. (3)
5. Draw receiver operating characteristics with all details (3)
6. Give the significance of Bayes risk (3)
7. Give the significance of linear models in estimation theory. (3)
8. Significance of Cramer-Rao Lower Bound in estimation. (3)
9. What is Minimum Variance Unbiased Estimation? (3)
10. Differentiate MAP and ML methods in estimation. (3)

PART B

*(Answer any **one** question from each module. Each question carries 14 marks each.)*

Note:
(1) Notation $x \sim \mathcal{N}(\mu, \sigma^2)$ denotes x is normally distributed with mean μ and variance σ^2.
(2)Also, bold small letters indicate vectors and bold capital letters indicate matrices.

11. Obtain the mathematical formulation of estimation method with an example. (14)

OR

12. Using radar system as an example, differentiate estimation and detection techniques. (14)

13. Design Neyman-Pearson detector for the unknown level A in White Gaussian Noise with variance σ^2. (14)

OR

14. Describe the Bayesian approaches in the design of detectors. (14)

15. Obtain Matched Filter detector for N-sample deterministic signal in noise, $w[n] \sim \mathcal{N}(0, \sigma_n^2)$ where $w[n]$'s are uncorrelated. (14)

OR

16. Describe estimator-correlator in the detection of random signals. (14)

17. Consider the multiple observations (14)

$$x[n] = A + w[n]; \quad n = 0, 1, \ldots, N-1$$

where $w[n] \sim \mathcal{N}(0, \sigma^2)$. Determine CRLB for A?

OR

18. Derive the Best Linear Unbiased Estimator for the multiple observations (14)

$$x[n] = A + w[n]; \quad n = 0, 1, \ldots, N-1$$

where A is an unknown level to be estimated and $w[n]$ is White Noise with unspecified PDF and variance σ^2.

19. Derive the Maximum Likelihood Estimator for the multiple observations (14)

$$x[n] = A + w[n]; \quad n = 0, 1, \ldots, N-1$$

where A is an unknown level to be estimated and $w[n]$ is White Gaussian Noise with known variance σ^2.

OR

20. Prove that the optimal estimator which minimizes the Bayesian Mean Square Error is the mean of the posterior PDF. (14)

ECT495	RF MEMS	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: This course introduces students to the rapidly emerging, area of MEMS with special emphasis on its applications in RF and wireless engineering

Prerequisite: Nil

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

CO1	Understand the various fabrication techniques and actuation mechanisms used in RF -MEMS design and apply them in practical situations
CO2	Explain the principle of operation of MEMS switches
CO3	Understand the construction and principle of operation of micromachined inductors and capacitors
CO4	Understand the construction and principle of operation of micromachined RF filters and phase shifters
CO5	Analyse the performance improvement of antenna due to micromachining techniques.
CO6	Identify the constraints in integration and packaging of RF MEMS devices

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3										
CO2	3	3										
CO3	3	3										
CO4	3	3										
CO5	3	3										
CO6	3	3					2					

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	20
Understand	30	30	60
Apply	10	10	20
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1): Understand the various fabrication techniques and actuation mechanisms used in RF -MEMS design and apply them in practical situations

1. Explain why Silicon evolved as the ideal substrate material for MEMS fabrication.
2. Explain any two thin film deposition processes as applied to MEMS fabrication.
3. Discuss the various fabrication challenges associated with surface micromachining.
4. List five applications of RF MEMS in our daily lives.
5. With a neat sketch explain the principle of operation of a MEMS piezoelectric actuator.

Course Outcome 2 (CO2): Explain the principle of operation of MEMS switches

1. Explain the various parameters to be considered in the design of RF switches
2. With neat sketches explain the construction and working of a shunt type RF MEMS switch

Course Outcome 3(CO3): Understand the construction and principle of operation of micromachined inductors and capacitors

1. With neat sketches explain one application each of gap-tuning and area tuning capacitors
2. Explain how inductance of micro machined inductors can be varied

Course Outcome 4 (CO4): Understand the construction and principle of operation of micromachined RF filters and phase shifters

1. Sketch and explain the principle of operation of a surface acoustic wave filter
2. Sketch and explain the principle of operation of any two types of micromachined Phase Shifters

Course Outcome 5 (CO5): Analyse the performance improvement of antenna due to micromachining techniques

1. Analytically justify the need for micro machined antennas. How can its performance be improved?
2. Explain the basic characteristics and design of microstrip antenna

Course Outcome 6 (CO6): Identify the constraints in integration and packaging of RF MEMS devices

1. List the types of MEMS packages
2. Explain the reliability issues associated with RF MEMS packaging

SYLLABUS

MODULE I

Introduction: RF MEMS for wireless applications, MEMS technology and fabrication, mechanical modeling of MEMS devices, MEMS materials and fabrication techniques-surface micromachining, Bulk micromachining, LIGA, Actuation Mechanisms in MEMS, Piezoelectric, Electrostatic, Thermal,Magnetic.

MODULE II

MEMS Switches: Introduction to MEMS switches; Capacitive shunt and series switches: Physical description, circuit model and electromagnetic modeling; Techniques of MEMS switch fabrication and packaging; Design of MEMS switches

MODULE III

Inductors and Capacitors: Micromachined passive elements; Micromachined inductors: Effect of inductor layout, reduction of stray capacitance of planar inductors, folded inductors, variable inductors and polymer-based inductors; MEMS Capacitors: Gap-tuning and area-tuning capacitors, dielectric tunable capacitors.

MODULE IV

RF Filters and Phase Shifters: Principle of operation of - micromachined filters, surface acoustic wave filters, micromachined filters for millimeter wave frequencies; Various types of MEMS phase shifters; Ferroelectric phase shifters

MODULE V

Micromachined antennas: Micromachining techniques to improve antenna performance, reconfigurable antennas.

Integration and Packaging: Role of MEMS packages, types of MEMS packages, module packaging, packaging materials and reliability issues.

Text Books:

1.Vijay Varadan, K. J. Vinoy, K. A. Jose, "RF MEMS and Their Applications", Wiley, 2003.

2. Hector J. De Los Santos,."RF MEMS Circuit Design for Wireless Applications", Artech House, 2002

References

1.Gabriel M. Rebeiz, "RF MEMS: Theory, Design, and Technology", Wiley, 2003

2.Eun Sok kim "Fundamentals of Micro electro mechanical Systems (MEMS)" McGraw Hill

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction to RF MEMS:** RF MEMS for wireless applications, ,	1
	MEMS technology and fabrication	1
	mechanical modeling of MEMS devices,	2
	MEMS materials	2
	MEMS fabrication techniques – Surface - Bulk Micromachining and LIGA	2
	Actuation Mechanisms in MEMS, Piezoelectric, Electrostatic, Thermal,Magnetic.	2
2	Introduction to MEMS switches	2
	Capacitive shunt and series switches: Physical description	2
	circuit model and electromagnetic modeling;	2
	Techniques of MEMS switch fabrication and packaging	2
	Design of MEMS switches	2
3	Inductors and Capacitors**:** Micromachined passive elements;	3
	Micromachined inductors: Effect of inductor layout reduction of stray capacitance of planar inductors	2
	folded inductors, variable inductors and polymer-based inductors	2
	MEMS Capacitors: Gap-tuning and area-tuning capacitors, dielectric tunable capacitors	2
4	RF Filters and Phase Shifters:Principle of operation - micromachined filters,	2
	surface acoustic wave filters,	2
	micromachined filters for millimeter wave frequencies	2
	Various types of MEMS phase shifters; Ferroelectric phase shifters	2

5	Micromachined antennas: Micromachining techniques to improve antenna performance	2
	reconfigurable antennas.	2
	Integration and Packaging: Role of MEMS packages, types of MEMS packages	2
	module packaging, packaging materials and reliability issues.	2

Model Question Paper

A P J ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SEVENTH SEMESTER B TECH DEGREE EXAMINATION
COURSE: ECT495 RF MEMS

Time: 3 Hrs **Max. Marks: 100**

PART A

Answer All Questions

1	List three applications of MEMS technology in RF communication devices	3
2	Explain why electrostatic actuation technique is preferred over magnetic actuation in MEMS devices.	3
3	List the advantages of cantilever switches	3
4	Mention the differences between series and shunt RF MEMS switches	3
5	Explain one key parameter used in the design of MEMS inductors	3
6	Which of the two MEMS capacitors - Area tuning and Gap tuning is preferred and why?	3
7	Explain the significance of Q factor in the design of MEMS filters	3
8	Explain one practical application of Phase shifters	3
9	What are the parameters to be optimised in the design of micro strip antennas	3
10	State three reliability issues in RF Microsystems packaging	3

PART B

Answer one question from each module. Each question carries 14 marks.

Module I

11(A)	Design a capacitor-based MEMS device for actuating the air-bag system in a passenger car. Show relevant diagrams. Compare it with a piezo electric based MEMS.	*7*
11(B)	With neat sketches explain the LIGA process. Also mention two applications of the same.	*7*
	OR	
12(A)	With neat sketches explain the steps in fabrication of two structures using bulk and surface micromachining.	*8*
12(B)	An ink jet printer needs a fast and efficient mechanism for ink dispensing.	*6*

Design a MEMS based system for this application. Give required sketches and equations.

Module II

13(A)	Explain the various parameters to be considered in the design of RF switches.	7
13(B)	With relevant equations explain how the pull-in voltage of cantilever beam type switches can be reduced. What are the integration and biasing issues for RF switches	7

OR

14(A)	With neat sketches explain the construction and working of a shunt type RF MEMS switch. Explain the RF MEMS design flow with a neat sketch.	10
14(B)	List the approaches used for low actuation voltage switching.	4

Module III

15(A)	With neat sketches describe the fabrication process of any micro machined inductor	7
15(B)	Explain how the capacitance can be varied for micro machined capacitors.	7

OR

16(A)	With neat sketches explain one application each of gap-tuning and area tuning capacitors.	6
16(B)	With the help of relevant equations show how inductance is varied in micro machined inductors.	8

Module IV

17(A)	Explain the realization of micro machined filters using resonators.	7
17(B)	Explain the principle of operation of any two types of phase shifters	7

OR

18(A)	With neat sketches explain the working of micromechanical filters using comb drives.	10
18(B)	Detailing the basic principles, mention two applications of MEMS phase shifters	4

Module V

19(A)	Explain the significance of reconfigurable antennas in satellite communication	7
19(B)	Discuss the reliability issues of MEMS packaging materials.	7

OR

20(A)	Explain the need for micro machined antennas with analytical justification. How can its performance be improved?	6
20(B)	Explain different types of MEMS packages	8

ECD496	MINIPROJECT	CATEGORY	L	T	P	CREDIT
		PWS	0	0	3	2

Preamble: The course aims

- To estimate the ability of the students in transforming the theoretical knowledge studied in to a working model of an electronic system
- For enabling the students to gain experience in organisation and implementation of small projects.
- Design and development of Small electronic project based on hardware or a combination of hardware and software for electronics systems.

Course Plan

In this course, each group consisting of three/four members is expected to design and develop a moderately complex electronic system with practical applications, this should be a working model. The basic concept of product design may be taken into consideration.

Students should identify a topic of interest in consultation with Faculty/Advisor. Review the literature and gather information pertaining to the chosen topic. State the objectives and develop a methodology to achieve the objectives. Carryout the design/fabrication or develop codes/programs to achieve the objectives. Demonstrate the novelty of the project through the results and outputs. The progress of the mini project is evaluated based on a minimum of two reviews.

The review committee may be constituted by the Head of the Department. A project report is required at the end of the semester. The product has to be demonstrated for its full design specifications. Innovative design concepts, reliability considerations, aesthetics/ergonomic aspects taken care of in the project shall be given due weight.

Course Outcomes

CO1	Be able to practice acquired knowledge within the selected area of technology for project development.
CO2	Identify, discuss and justify the technical aspects and design aspects of the project with a systematic approach.
CO3	Reproduce, improve and refine technical aspects for engineering projects.
CO4	Work as a team in development of technical projects.
CO5	Communicate and report effectively project related activities and findings.

Mapping of course outcomes with program outcomes

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

Evaluation

The internal evaluation will be made based on the product, the report and a viva- voce examination, conducted by a 3-member committee appointed by Head of the Department comprising HoD or a senior faculty member, Academic coordinator for that program, project guide/coordinator.

The Committee will be evaluating the level of completion and demonstration of functionality/specifications, presentation, oral examination, work knowledge and involvement.

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	75	75	1 hour

Split-up of CIE

Component	Marks
Attendance	10
Marks awarded based on guide's evaluation	15
Project Report	10
Evaluation by Committee	40

Split-up of ESE

Component	Marks
Level of completion	10
Demonstration of functionality	25
Project Report	10
Viva-voce	20
Presentation	10

ECT497	DESIGN AND ANALYSIS OF ANTENNAS	CATEGORY	L	T	P	CREDIT
		VAC	4	0	0	4

Preamble: This course aims to impart knowledge on the basic parameters, matching techniques, design and working of various broad band antennas, practical antennas, antenna arrays and its radiation patterns. It also introduces standard software to design antennas with a set of given specifications.

Prerequisite: ECT 302 ELECTROMAGNETICS, ECT 401 MICROWAVE AND ANTENNAS

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

CO1-K2	Understand the concept of radiation mechanism, antenna parameters and antenna matching techniques.
CO2-K2	Illustrate the far filed pattern of different types of antennas.
CO3-K3	Analyze different types of broad band antennas and its radiation patterns.
CO4-K3	Design of various practical antennas, antenna arrays and field patterns.
CO5-K3	Familiarize Antenna Design Software and design microstrip patch antenna.

Mapping of course outcomes with program outcomes:

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

Assessment Pattern:

Bloom's Category		Continuous Assessment Tests		End Semester Examination
		1	2	
Remember				
Understand	K2	20	20	40
Apply	K3	30	30	60
Analyse				
Evaluate				
Create				

Mark distribution:

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 Hours

Continuous Internal Evaluation Pattern:

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

End Semester Examination Pattern

Maximum Marks: 100 **Time: 3 hours**

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the steps involved in the design of a T-match circuit.
2. With the help of neat sketches explain the working of a Rhombic Antenna and its features.
3. Explain omega match.
4. Calculate the Directivity of an antenna with field pattern given by,

$$E = E_{\vartheta} = \frac{\mu}{4\pi r} \mathrm{e}^{-jkr} \cos^2 \phi \sin^2 \theta, 0 \le \theta \le \pi, 0 \le \phi \le 2\pi$$

5. Derive the vector potential for an electric current source J.
6. Explain the optimum design of rhombic antenna.
7. Derive expressions for the Far Field components and Radiation Resistance and Directivity of a half wave dipole antenna.

Course Outcome 2 (CO2):

1. Explain the axial mode and normal mode of operation of a helical antenna.
2. Derive the expressions for the fields radiated by a circular loop antenna.
3. Explain field equivalence principle and give the step to form an equivalent and aperture problem.
4. Explain solution of Hallen's Integral equation using delta gap model.

Course Outcome 3 (CO3):

1. Discuss about any two feeding techniques for Microstrip Antenna.
2. List the important features of a Yagi-Uda Antenna.
3. Design an aperture antenna, with uniform illumination, so that the directivity is maximized at an angle $30^0$from the normal to the aperture. Determine the optimum dimension and its associated directivity when the aperture is (i) square (ii) circular.
4. Design a Microstrip patch antenna for 2.4 GHz. The patch substrate has a dielectric of 2.2 and with height 2.2 mm.

Course Outcome 4 (CO4):

1. Explain the working of Lens Antenna. What do man by zoning in Lens Antenna?
2. Design a broad side Dolph-Tscebycheff array of 10 elements with spacing *d*between the elements and with a major to minor lobe ratio of 26 dB. Find the excitation coefficients and form the array factor.
3. Derive general expression for array factor of non-isotropic antennas.
4. Derive expression for array factor of N isotropic sources for end-fire array and also the expression for major lobe, minor lobes and Nulls of the array.
5. Calculate the half-power beam width and directivity for the Dolph-Tchebyscheff array of lobe ratio 26 dB for a spacing of $\lambda/2$ between the elements.
6. Design an 8 element broadside array of isotropic sources having λ/2 spacing between the elements .The pattern is to be optimized with a side lobe -25dB down the minor lobe maxima.

Course Outcome 5 (CO5):

1. Design a rectangular patch antenna operates at 5.5GHz.Use FR4/Duroid RT5870 as the substrate of patch antenna. Determine the thickness from data sheet. Write a procedure in order to design desired antenna by giving all equations , dimensions and simulation results (using MATLAB/HFSS/CST Microwave Studio or any Open software)
2. By using the rectangular patch antenna which is designed in Question no 1 as unit element, designing 1x4 array antennas at 5.5GHz on FR4/Duroid RT 5870 substrate. Determine the optimum distance between the unit element using HFSS and also give simulation results (radiation pattern, VSWR plot etc.).

Syllabus

Module	Course contents	Hours
I	Review of Antenna Parameters: -Polarization, Input impedance, Gain. Relation between radiation fields and magnetic vector potential – Helmholtz equation and Lorentz conditions. Antenna matching –T match, Baluns, Gamma and Omega match.Review of dipole antennas (short dipole and arbitrary length), Monopole antennas, Vand rhombic antennas. Folded dipole and it's properties.	9
II	Analysis of Circular Loop and Biconical Antenna. Helical Antennas (normal mode and axial mode) – relation for far fields, radiation resistance and gain.Current induced in a dipole antenna – Pocklington and Hallen's integral equations. Solution of Hallen's integral equation for current induced in a dipole antenna for delta gap model.	9
III	Near fields of linear antennas, self and mutual impedance, arrays of parallel dipoles, Yagi-Uda antennas.Aperture antenna – Field equivalence principle. Radiation from open-ended wave-guides, horn antennas, horn radiation fields, horn directivity, optimum horn design, Rectangular micro-strip antennas –field analysis and design.Designing an antenna with a set of given specifications using standard software (MATLAB/HFSS/CST Microwave Studio or any Open software)	10
IV	Parabolic reflector antennas, gain and beam width of reflector antennas, aperture-field and current distribution methods, radiation patterns of reflector antennas, dual-reflector antennas, lens antennas -hyperbolic lens and zoned lens. Frequency independent antennas – Rumsey Principle – Spiral Antennas. Design of log periodic dipole arrays.	8
V	Antenna arrays – General expression for array factor. Grating lobes. One dimensional arrays- Broad side, end fire and Chebyshev arrays. Concept of beam steering. Design of array using Schelkunnof's zero placement method and Fourier series method. Woodward-Lawson frequency-sampling design, Narrow beam design and Butler matrix beam former. Adaptive Beam forming. 2D arrays – Rectangular and Circular array.	9

Text Books:

1. Sopholes J. Orfanidis – Electromagnetic waves and antennas. Available at: http://eceweb1.rutgers.edu/~orfanidi/ewa/
2. Consrantive A Balanis -Antenna Theory - Analysis and Design – 2/e John Wiley & Sons.
3. John D. Krans, Ronald J. Marhefka : Antennas for all Applications , 3/e, TMH
4. Thomas A Milligan – Modern Antenna Design, 2/e John Wiley & Sons.

References:

1. Collin R.E, Antennas & Radio Wave Propagation, McGraw Hill. 1985.
2. Jordan E.C. & K. G. Balmain, Electromagnetic Waves & Radiating Systems, 2/e, PHI.
3. Raju G.S.N., Antenna and Wave Propagation, Pearson, 2013.
4. Sisir K.Das & Annapurna Das, Antenna and Wave Propagation, McGraw Hill,2012

Course Contents and Lecture Schedule.

No	Topic	No.of. Lectures
	Module I	
1.1	Basic antenna parameters (all parameters and related simple problems), Relation between parameters (derivation required)	1
1.2	Relation between radiation fields and magnetic vector potential – Helmholtz equation and Lorentz conditions.	2
1.3	Antenna matching –T match, Baluns, Gamma and Omega match.	2
1.4	Review of dipole antennas (short dipole and arbitrary length),	2
1.5	Monopole antennas, Vand rhombic antennas. Folded dipole and it's properties.	2
	Module II	
2.1	Analysis of Circular Loop and Biconical Antenna.	2
2.2	Helical Antennas (normal mode and axial mode) – relation for far fields, radiation resistance and gain.	2
2.3	Current induced in a dipole antenna – Pocklington and Hallen's integral equations.	3
2.4	Solution of Hallen's integral equation for current induced in a dipole antenna for delta gap model.	2
	Module III	
3.1	Near fields of linear antennas, self and mutual impedance, arrays of parallel dipoles, Yagi-Uda antennas.	2
3.2	Aperture antenna – Field equivalence principle.	2
3.3	Radiation from open-ended wave-guides, horn antennas, horn radiation fields, horn directivity, optimum horn design,	2
3.4	Rectangular micro-strip antennas – Field analysis and design.	2
3.5	Designing an antenna with a set of given specifications using standard software(MATLAB/HFSS/CST Microwave Studio or any Open software).	2
	Module IV	
4.1	Parabolic reflector antennas, gain and beam width of reflector antennas, aperture-field and current distribution methods, radiation patterns of reflector antennas,	2
4.2	Dual-reflector antennas, lens antennas -hyperbolic lens and zoned lens.	2
4.3	Frequency independent antennas – Rumsey Principle – Spiral Antennas.	2
4.4	Design of log periodic dipole arrays.	2
	Module V	
5.1	Antenna arrays – General expression for array factor. Grating lobes.	1
5.2	One dimensional arrays- Broad side, end fire and Chebyshev arrays. Concept of beam steering.	2

5.3	Design of array using Schelkunnof's zero placement method and Fourier series method.	**2**
5.4	Woodward-Lawson frequency-sampling design, Narrow beam design and Butler matrix beam former.	**2**
5.5	Adaptive Beam forming. 2D arrays – Rectangular and Circular array.	**2**

Simulation Assignments (ECT 477)

The following simulation assignments can be done with MATLAB/HFSS/CST Microwave Studio or any Open software.

- Design a rectangular microstrip antenna (using MATLAB) for 1.8 GHz with RT-Duroid 5880 FR4 substrate having permittivity 4.4, loss tangent=0.001 and h=1.6mm and also plot 3D, 2D radiation patterns and VSWR.
- The dimensions of a rectangular microstrip antenna are: L=3.733cm and W=3.973 cm. The substrate height h=1.6mm and dielectric constant = 4.4.If operating frequency is 1.8 GHz.Write a MATLAB program to calculate

    (a) The input impedance
    (b) The position of the inset feed point for matching to 50 ohm feeder line.

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd. 2014

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B. TECH DEGREE EXAMINATION

Course Code: ECT497

Course Name: DESIGN AND ANALYSIS OF ANTENNAS

Max. Marks: 100 Duration: 3 Hours

PART A

(*Answer All Questions*)

1	Using Lorentz condition show that $\nabla^2 A + k^2 A = -\mu J$	(3)
2	Explain design procedure of Gamma match.	(3)
3	Derive expression for input impedance of a folded dipole antenna.	(3)
4	Derive radiated fields for a circular loop of constant current.	(3)
5	Explain the delta gap model in dipole antennas.	(3)
6	Derive the expression for far field pattern of an open ended wave guide.	(3)
7	Discuss about the Frequency Sampling Technique for Array Design.	(3)
8	Explain the working of Spiral Antenna. Derive appropriate expressions.	(3)
9	Design an Antenna Array using Schelkunnoff's Zero Placement technique.	(3)
10	Explain Butler Matrix Beam Forming.	(3)

PART B

(*Answer one question from each module. Each question carries 14 marks*)

MODULE I

11 a)	Derive the relation between magnetic vector potential and radiation fields in antennas, stating clearly Helmholtz equation and Lorentz conditions.	(9)
b)	An antenna with overall length $l = 5\lambda$ the observations are made at $r = 60\lambda$. Find the errors in phase and amplitude using far field approximation.	(5)

OR

12a)	Derive expressions for the Far Field components and Radiation Resistance and Directivity of a short dipole antenna.	(6)
b)	Derive the self and mutual impedance of two parallel Centers driven coupled dipole antennas.	(8)

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MODULE II

13 a) Design an axial mode helical antenna for directivity 28 dBi for operating at 600 MHz. Calculate the radiation resistance, HPBW, BWFN and bandwidth of the designed antenna. (5)

b) Derive Pocklington's and Hallen's Integral Equation. Explain their significance. (9)

OR

14 a) Explain the Field Equivalence Principle in detail. (5)

b) Derive the expressions for power density, radiation resistance, and directivity of Circular loop antenna. (9)

MODULE III

15 a) Design a rectangular Microstrip antenna resonating at 2 GHz. The antenna uses a substrate with a dielectric of 10.2 and the height of the substrate is 0.3 cm. (8)

b) Derive expressions for the Directivity of a Horn Antenna. (6)

OR

16a) Design a Yagi-Uda array with a directivity of 9.2 dB at $f_0 = 50MHz$. The desired diameter of the parasitic elements is 2.54 cm and of the metal supporting boom 5.1 cm. Find the element spacing, lengths and total array length. (7)

b) State Huygens' Principle and discuss field equivalence in aperture antennas. (7)

MODULE IV

17a) Design a LPDA with τ = 0.85, σ = 0.03 for the frequency range 15-45 MHz. (7)

b) Explain the working of a parabolic dish antenna. Write down the expression for gain, HPBW and BWFN. (7)

OR

18 a) Derive Rumsey Principle for frequency independent antennas. (7)

b) Why equiangular spiral antenna and log periodic antennas are called frequency independent antennas. Explain their working. (7)

MODULE V

19 a) Design an antenna array using Schelkunoff's zero placement method. (7)

b) Design a 5 element Dolph-Tscebycheff array with peak side lobe level 22 dB. (7)

OR

20 a) Design an antenna array using Woodward-Lawson Frequency Sampling technique. (8)

b) Derive the array factor of 90^0 corner reflector. (6)

ECT499	MULTIRATE SIGNAL PROCESSING AND WAVELETS	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: The aim of this course is to introduce the idea of wavelets, and the related notions of time frequency analysis, of time-scale analysis, and to describe the manner in which technical developments related to wavelets have led to numerous applications. The concepts of multirate filter banks is also introduced. The relation between wavelets and multirate systems is brought out to illustrate how wavelets may actually be realized in practice**.**

Prerequisite: ECT 303 Digital Signal Processing

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

CO 1	Understand the concepts, properties and interconnection of Multirate systems, Wavelets and Filterbanks and apply them in the analysis of signal processing systems.
CO 2	Construct wavelets and multirate systems using the time domain and the frequency domain approaches.
CO 3	Apply the wavelet transform, wavelet packet transform and its variants as a tool in 1-D and 2-D signal analysis and processing.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category		Continuous Assessment Tests		End Semester Examination
		1	2	
Remember	K1	10	10	10
Understand	K2	20	10	20
Apply	K3	10	20	50
Analyse	K4	10	10	20
Evaluate				
Create				

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1): Understand the concepts, properties and interconnection of Multirate systems, Wavelets and Filter banks and apply them in the analysis of signal processing systems.

1. Explain the basic building blocks of a multirate/ multi resolution analysis system.
2. Analyse the frequency domain behavior of the rate conversion operations to build analysis and synthesis filters of a filter bank.
3. Analyse the time-frequency behaviour of signals through various analysis tools such as Fourier Transform, Short Time Fourier Transform(STFT) and wavelet transform and compare their properties.
4. What are the properties of a wavelet basis functions and what are the advantages of representing signals using them.

Course Outcome 2 (CO2): Construct wavelets and multirate systems using the time domain and the frequency domain approaches

1. Construct different families of wavelets using the filter bank approach.
2. Construct different families of wavelets using frequency domain approach.
3. Establish the relationship between filterbanks and wavelets to construct efficient wavelet based analysis-synthesis systems.

4. Design appropriate analysis and synthesis filters using the z-domain analysis that satisfy the properties of a wavelet system.

Course Outcome 3 (CO3): Apply the wavelet transform, wavelet packet transform and its variants as a tool in 1-D and 2-D signal analysis and processing.

1. Explain the wavelet packet transform and its implantation using filterbanks.
2. Explain the construction of the filter bank for the analysis of 2-D signals.
3. How will you choose wavelets for various applications? What properties of wavelets are suited for different applications? Analyse and study with respect to the application point of view

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SYLLABUS

Module 1: Basics of Multirate processing and Filter banks

Introduction to multiresolution and multirate signal processing with some example applications, Multirate System Fundamentals: Basic multirate operations – Decimation and Interpolation, Transform domain analysis of Decimators and Interpolators, Decimation and Interpolation filters, Fractional sampling rate alteration Interconnection of decimators and interpolators, The Noble Identities.
Introduction to digital filter banks, The DFT filter bank, Two Channel Quadrature Mirror Filterbank (QMF), Two channel Conjugate Quadrature Filter Bank (CQF). Perfect Reconstruction.

Module 2: Introduction to Wavelet Transform

The Uncertainty Principle - Time-bandwidth product uncertainty, The time frequency plane and its tilings, Short Time Fourier Transform, The Gabor Transform and its generalization, Wavelet Transform in general and origin of Wavelets. The Continuous Wavelet Transform (CWT), Condition of admissibility and its implications.
Introduction to Discrete Wavelet Transform (DWT), DWT from CWT, Logarithmic Scale Discretization and Dyadic Discretization, Families of wavelets: Orthogonal and biorthogonal wavelets, Vanishing moments and regularity.

Module 3: The Multiresolution Analysis (MRA), Wavelets and Filter Banks

The Multiresolution Analysis: The Dyadic Haar Multiresolution Analysis - The Haar Scaling Functions and Function spaces, Nested spaces, The Haar Wavelet function, Orthogonality of the Haar Scaling and Wavelet functions. Relating Scaling and Wavelet functions of Haar and Filters, The Haar Filter Bank, Z-domain analysis of Haar filter bank.
The Daubechies' family of MRA, Daubechies' Filter banks, Relating QCF filter banks and Daubechies' wavelets.

Module 4: Biorthogonal Wavelets

Introduction to biorthogonal vector space, Biorthogonal Wavelet Systems, Signal representation using Biorthogonal Wavelet System, Construction of Biorthogonal wavelets Design of Wavelet systems using frequency domain approach – Frequency domain characterisation of filter coefficients, Design of Daubechies Wavelets using frequency domain approach, JPEG 2000 5/3 filter bank and Spline MRA.

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Module 5: Wavelet packets and 2-D DWT

The wavelet packet transform, Best wavelet packet tree, Noble identities and the Haar wave Packet Transform. Introduction to 2-D DWT, Wavelet transform of an image, The Embedded Zero-tree Wavelet (EZW) Coding. Applications of wavelets in audio & image compression and denoising.

Text Books

1. P. P. Vaidyanathan, Multirate Systems and Filter Banks, Pearson Education, 2006.
2. K. P. Soman, K. I. Ramachandran, "Insight Into Wavelets - From Theory to Practice", Prentice Hall of India, 3rd Edition, Eastern Economy Edition, Prentice Hall of India Private Limited, 2010. Video lectures and Transcripts: Adv. Digital Signal Processing: Multirate and Wavelet NPTEL Lecture series - https://nptel.ac.in/courses/117/101/117101001/

Reference Books

1. Gilbert Strang and Truong Q. Nguyen, Wavelets and Filter banks, 2nd Edition, Wellesley- CambridgePress,1998
2. Raghuveer M. Rao, Ajit S. Bopardikar, “Wavelet Transforms: Introduction to Theory and Applications, Prentice Hall, 1998.
3. N.J. Fliege, Multirate Digital Signal Processing, John Wiley, 1999.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Basics of Multirate processing and Filter banks**	
1.1	Introduction to multiresolution and multirate signal processing with some example applications.	1
1.2	Multirate System Fundamentals: Basic multirate operations – Decimation and Interpolation, Transform domain analysis of Decimators and Interpolators, Decimation and Interpolation filters.	2
1.3	Fractional sampling rate alteration	1
1.4	Interconnection of decimators and interpolators, The Noble Identities.	1
1.5	Introduction to digital filter banks, The DFT filter bank.	2
1.6	Two Channel Quadrature Mirror Filterbank (QMF)	1
1.7	Two Channel Conjugate Quadrature Filter Bank (CQF). Perfect Reconstruction.	2
2	**Introduction to Wavelet Transform**	

2.1	The Uncertainty Principle - Time-bandwidth product uncertainty, The time frequency plane and its tilings.	2
2.2	Short time Fourier Transform, The Gabor Transform and its generalization, Wavelet Transform in general and origin of Wavelets.	2
2.3	The Continuous Wavelet Transform (CWT), Condition of admissibility and its implications.	2
2.4	Introduction to Discrete Wavelet Transform (DWT), DWT from CWT, Logarithmic Scale Discretization and Dyadic Discretization	1
2.5	Families of wavelets: Orthogonal and biorthogonal wavelets, Vanishing moments and regularity.	2
3	**The Multiresolution Analysis (MRA), Wavelets and Filter Banks**	
3.1	The Multiresolution Analysis: The Dyadic Haar Multiresolution Analysis - The Haar Scaling Functions and Function spaces, Nested spaces, The Haar Wavelet function, Orthogonality of the Haar Scaling and Wavelet functions.	3
3.2	Relating Scaling and Wavelet functions of Haar and Filters, The Haar Filter Bank, Z-domain analysis of Haar filter bank.	3
3.3	The Daubechies' family of MRA, Daubechies' Filter banks, Relating QCF filter banks and Daubechies' wavelets.	3
4	**Biorthogonal Wavelets**	
4.1	Introduction to biorthogonal vector space, Biorthogonal Wavelet Systems.	2
4.2	Signal representation using Biorthogonal Wavelet System, Construction of Biorthogonal wavelets	2
4.3	Design of Wavelet systems using frequency domain approach – Frequency domain characterisation of filter coefficients, Design of Daubechies Wavelets using frequency domain approach.	3
4.4	JPEG 2000 5/3 filter bank and Spline MRA.	1
5	**Wavelet packets and 2-D DWT**	
5.1	The wavelet packet transform, Best Wavelet packet tree, Noble identities and the Haar wave Packet Transform.	3
5.2	Introduction to 2-D DWT, Wavelet transform of an image	3
5.3	The Embedded Zero-tree Wavelet (EZW) Coding.	1
5.4	Applications of wavelets in audio & image compression and denoising	2

Course Projects:

1. Study the spectral characteristics of Down sampler (Decimator) and Up sampler (Interpolator).
2. Implement a 2- channel QMF/QCF filterbank and observe and syudy the ouput at every stage of the filter bank.
3. Study the effect of sample rate conversion (Down sampling and Up sampling) on audio data or on your own recorded speech.
4. Generate and plot the scaling and wavelet functions of Daubechies' wavelets using recursion/iterative method.
5. Study the equivalence of Haar multi resolution analysis and Haar filter bank for a piecewise linear function.
6. Implement a biorthogonal 5/3 filter bank used in JPEG2000 standard.
7. Read an image and apply 2-D wavelet transform on it. Observe and study the contribution of various subbands by reconstructing the image using selective subbands.
8. Study and implementation of Wavelet Packet Transform and best wavelet packet tree.
9. Read an image and apply 2-D wavelet transform on it. Apply thresholding on the wavelet coefficients of different subband based on energy of the coefficient and reconstruct the signal. Compute the compression obtained and the quality of the reconstructed image (PSNR) by varying the thresholds.
10. Apply Wavelet transform on noisy data and implement various wavelet based denoising methods

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION,

(Model Question Paper)

Course Code: ECT499

Course Name: MULTIRATE SIGNAL PROCESSING AND WAVELETS

Max. Marks: 100 Duration: 3 Hours

PART A

Answer ALL Questions. Each Carries 3 mark.

1	Illustrate the frequency domain behavior of a decimator.	K2
2	State and prove the noble identities for the multirate systems.	K1
3	Explain dyadic discretization of constructing DWT from CWT	K2
4	Explain Gabor transform. What is its drawback?	K2
5	Explain the concept of nested spaces in multirate Analysis.	K3
6	Establish the relationship between QCF Filterbank and Daubechies wavelet.	K3
7	Explain the concept of biorthogonal vector space	K2
8	When will you go for biorthoganal wavelet trasforms rather than orthogonal wavelet transform. Specify any one application where biorthogonal wavelet transform is used.	K2
9	What are the advantages of Wavelet Packet Transform over Wavelet Transform?	K2
10	Give a block schematic of 2-D wavelet decomposition and explain the construction of image subbands.	K2
	PART – B Answer one question from each module; each question carries 14 marks.	
	Module - I	

11 a. b.	Show that the decimator and interpolator are linear time varying systems For the system shown in Figure below, find the expression for y(n) in terms of x(n). x(n) ↑3 ↓2 ↓3 ↑2 y(n)	7 7 CO1 K3

	OR	
12 a.	Draw the block diagram of a 2-channel Quadrature Mirror Filterbank (QMF) and derive the expression for the output using z-domain analysis. What is the condition for alias cancellation? How will you construct an alias free QMF?	14 CO1 K2
	Module - II	
13 a.	Derive Heisenberg's uncertainty principle relating the time and frequency resolutions. Prove that if the window function is Gaussian, equality holds.	7 CO1 K2
b.	Briefly explain the difference between Fourier Transform, Short Time Fourier Transform (STFT) & Wavelet Transform.	7 CO1 K3
	OR	
14 a. b.	State and prove the admissibility conditions of a wavelet. Check whether the following function is an admissible wavelet? $e^{-t^2}\cos\left(\pi\sqrt{\frac{2}{\ln 2}}\,t\right)$	7 7 CO2 K4
	Module - III	
15 a.	Find two level Haar Wavelet transform using the analysis filters $\{h(-k)\} = \left\{\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}\right\}$ & $\{g(-k)\} = \left\{\frac{1}{\sqrt{2}}, \frac{-1}{\sqrt{2}}\right\}$ for the following sequence. [1, 0, -3, 2, 1, 0, 1, -2] Remove from the Wavelet transform, the coefficients between –1 & 1 and then reconstruct the function and compute Mean Squared Error.	14 CO2 K3

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	OR	
16	Let $\varphi(t)$ and $\psi(t)$ be the Haar scaling and wavelet functions. Let Vj and Wj be the spaces spanned by $\varphi_{j,k}(t) = 2^{j/2}\varphi(2^j t - k)$ and $\psi_{j,k}(t) = 2^{j/2}\psi(2^j t - k)$, respectively. Let f(t) be defined on $0 \le t < 1$ and given by $f(t) = \begin{cases} -1 & 0 \le t < 1/4 \\ 4 & 1/4 \le t < 1/2 \\ 2 & 1/2 \le t < 3/4 \\ -3 & 3/4 \le t < 1 \end{cases}$ 1. Express f in terms of the basis for V2. 2. Decompose f into its component parts in W1, W0, and V0. In other words, find the Haar wavelet decomposition for f. 3. Sketch each of the four decompositions..	14 CO2 K3
	Module - IV	
17	Prove that in a Bi-orthogonal Wavelet System $\sum_k h(k) = \sum_k \tilde{h}(k) = \sqrt{2}$ $\sum_k \tilde{h}(k)\, h(k - 2l) = \delta_{l,0}$.	14 CO1 K3
	OR	
18	Construct db2 wavelet using time domain approach.	14 CO2 K2
	Module - V	
19	Discuss the application of wavelet analysis in Audio Coding and Signal Denoising. Compare wavelet based denoising technique with FFT based denoising method	14 CO3 K2
	OR	

20 a.	Explain the Embedded Zero-tree Wavelet (EZW) algorithm used in image compression.	7 CO3 K2
b.	For the seven-level decomposition shown below, 21 6 15 12 -6 3 6 3 3 -3 0 -3 3 0 0 0 Find the bit stream or labels generated by the Embedded Zerotree Wavelet (EZW) coder, after three steps of multiple pass procedure. Also, determine the list of significant coefficients.	7 CO3 K3

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