AEEE503 - Random Variables and Stochastic Processes

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<tr><td>Course Title</td><td colspan="5">Random Variables and Stochastic Processes</td></tr>
<tr><td>Course Code</td><td colspan="5">AEEE503</td></tr>
<tr><td>Course Type</td><td colspan="5">Technical Elective</td></tr>
<tr><td>Level</td><td colspan="5">MSc (Level 2)</td></tr>
<tr><td>Year / Semester</td><td colspan="5">1- or 2</td></tr>
<tr><td>Teacher’s Name</td><td colspan="5">Assoc. Prof. Marios Lestas</td></tr>
<tr><td>ECTS</td><td>8</td><td>Lectures / week</td><td>3</td><td>Laboratories/week</td><td>0</td></tr>
<tr><td>Course Purpose</td><td colspan="5">The aim of the course is to familiarize students with the theory of probability, random variables and stochastic processes and use the theoretical foundations to analyze and solve practical problems in electrical engineering with reference to examples from the fields of communications and control.</td></tr>
<tr><td>Learning Outcomes</td><td colspan="5">By the end of the course, students must be able to:
1. Recognize key concepts of set theory: Sample Spaces, Events, Sigma-fields.
2. Present the axiomatic definition of Probability and use it introduce the concepts of Conditional Probability, Total Probability and Independence.
3. Apply Bayes’ theorem and examine applications related to communication over noisy channels.
4. Define Random Variables and related concepts such as the Probability Distribution Function, the Probability Density Function, the Expected Value of a Random Variable, Conditional Expectations, Moments, Moment Generating Functions and Characteristic Functions.
5. Recognize the univariate Normal (Guassian) probability density function and its significance in practical applications.
6. Analyze Functions of Random Variables with reference to concepts such as conditional and joint distributions and densities.
7. Recognize key concepts of Linear Algebra: Multiplication, Linear Dependence, Determinants, Eigenvalues, Eigenvectors, Positive Definite Matrices, Causal Factorization, Spectral Resolution.
8. Define the Covariance and Correlation Matrices of Random Vectors and analyze Linear Transformation of Random Vectors.
9. Define Gaussian Functions, Gaussian Characteristic Functions, and the probability density function of a Gaussian random vector.
10. Perform Hypothesis Testing with second order information and investigate Correlation Detection in Additive Noise and Whitening,
11. Present Bayes decision theory and analyse applications such as</td></tr>
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<tr><td></td><td colspan="3">minimization of probability of error, Likelihood ratio tests and Mean Square Estimation.
12. Define Stochastic Processes and identify key processes such as Wiener Process, Markov Process, Poisson Process
13. Analyze applications related to random processes such as Modulation, Kalman Filtering Power Spectral Density and Queueing Theory.</td></tr>
<tr><td>Prerequisites</td><td>None</td><td>Corequisites</td><td>None</td></tr>
<tr><td>Course Content</td><td colspan="3">Introduction to Probability: Overview of set theory. Sample Spaces, Events, Sigma-fields, Axiomatic Definition of Probability, Joint Probabilities, Conditional Probabilities, Total Probability, Independence, Bayes’ theorem and applications, Communication over noisy channels.

Random Variables: Definition of Random Variables, Probability distribution function, Probability density function, Conditional and joint distributions and densities, Functions of Random Variables, Expected Value of a Random Variable, Conditional Expectations, Moments, Joint Moments, Moment Generating Functions, Characteristic Functions.

Revision on Linear Algebra: Multiplication, Linear Dependence, Determinants, Eigenvalues, Eigenvectors, Positive Definite Matrices, Causal Factorization, Spectral Resolution.

Second Moment Descriptions: Covariance, Correlation, Linear Transformation of Random Vectors, the Simulation Problem, Gaussian Functions, Gaussian Characteristic Functions, Linear Transformations, The probability density function of a Gaussian random vector.

Applications using Second Order Information: Hypothesis Testing with second order information, Correlation Detection in Additive Noise, Whitening, Bayes decision theory, Minimization of probability of error, Likelihood ratio tests, Mean Square Estimation.

Stochastic Processes: Definition of Random Processes, Examples of Random Processes, Phase Shift Keying, Wiener Process, Markov Processes, Poisson Processes, Stationarity, Power Spectral Density, Kalman Filtering.</td></tr>
<tr><td>Teaching Methodology</td><td colspan="3">Students are taught the course through lectures (3 hours per week) in classrooms or lectures theatres, by means of traditional tools or using computer demonstration.

Auditory exercises, where examples regarding matter represented at the lectures, are solved and further, questions related to particular open-ended topic issues are compiled by the students and answered, during the lecture or assigned as homework.

Topic notes are compiled by students, during the lecture which serve to cover the main issues under consideration and can also be downloaded from the e-learning platform or the lecturer’s webpage. Students are also advised to use the subject’s textbook or reference books for further reading and practice in solving related exercises. Tutorial problems are also submitted as homework and these are solved during lectures or privately during lecturer’s office hours.</td></tr>
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	Furthermore, design projects may be assigned to the students, where literature search is encouraged to identify a specific problem related to some issue, gather relevant scientific information about how others have addressed the problem, implement to implement the design and report the results in written or orally. Where appropriate, taught material as well as examples and design problems are drawn from the recent research activities of the lecturer or other faculty members.
Bibliography	**(a) <u>Textbooks:</u>** • Henry Stark, John W. Woods, **Probability and Random Processes**, Prentice Hall, 2002. • Athanasios Papoulis, S. Unnikrishna Pillai, **Probability, Random Variables and Stochastic Processes**, McGraw-Hill Science, 2001. **(b) <u>References:</u>** • Alberto Leon-Garcia, **Probability and Random Processes for Electrical Engineering**, Addison Wesley, 1994 • Carl W. Helstrom, ***Probability and Stochastic Processes for Engineers***, McMillan, 2nd Edition, 1991.
Assessment	The Students are assessed via continuous assessment throughout the duration of the Semester, which forms the Coursework grade and the final written exam. The coursework and the final exam grades are weighted 40% and 60%, respectively, and compose the final grade of the course. Various approaches are used for the continuous assessment of the students, such as mid-term written exam, oral exam, quizzes, design assignments and design projects. The assessment weight, date and time of each type of continuous assessment is being set at the beginning of the semester via the course outline. An indicative weighted continuous assessment of the course is shown below: • Assignments 10% • Homework 10% • Mid-Term written exams 40% • Design Project 20% • Quizzes 20% Students are prepared for final exam, by revision on the matter taught, problem solving and concept testing and are also trained to be able to deal with time constrains and revision timetable. The criteria considered for the assessment of each type of the continuous assessment and the final exam of the course are: (i) the comprehension of the fundamental concepts and theory of each topic, (ii) the application of the theory in solving related problems and (iii) the ability to apply the above knowledge in more complex design problems. The above criteria are weighted 30%, 40% and 30%, respectively. The final assessment of the students is formative and summative and is assured to comply with the subject’s expected learning outcomes and the quality of the course
Language	**English**