National University of Engineering (UNI)
School of Civil Engineering
Syllabus 2027-I

1. COURSE

STA251. Statistics and Probability (Mandatory)

2. GENERAL INFORMATION

2.1 Course	:	STA251. Statistics and Probability
2.2 Semester	:	4th Semester.
2.3 Credits	:	3
2.4 Hours	:	1 HT; 4 HP;
2.5 Duration of the period	:	16 weeks
2.6 Type of course	:	Mandatory
2.7 Learning modality	:	Face to face
2.8 Prerrequisites	:	MA112. Calculus II. (2nd Sem)

3. PROFESSORS

Meetings after coordination with the professor

4. INTRODUCTION TO THE COURSE

Probability and statistics provide the mathematical foundation for reasoning under uncertainty, analyzing data, and building predictive models – skills that are essential across computing, artificial intelligence, computational mathematics, and engineering alike. This course develops a rigorous understanding of probability theory and its use in describing random phenomena, together with the fundamentals of descriptive statistics, statistical inference (estimation, hypothesis testing, and Bayesian reasoning), and regression modeling, so that students can summarize and analyze data, quantify uncertainty, and draw sound quantitative conclusions in their own field of application.

5. GOALS

- Understand the fundamentals of probability theory and descriptive statistics.
- Apply probability distributions and statistical inference methods to analyze data and quantify uncertainty.
- Develop skills to model random phenomena and build predictive statistical models such as linear regression.

6. COMPETENCES

ABET-1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. (Familiarity)

7. TOPICS

Unit 1: Numerical Summaries: Location, Spread, and Shape (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Measures of location: mean, median, mode, trimmed mean, and weighted mean • Measures of spread: variance, standard deviation, IQR, MAD, and range • Measures of shape: skewness and kurtosis; quantiles and percentiles • Robust summary statistics: resistance to outliers and heavy-tailed distributions	• Calculate and interpret measures of location, spread, and shape for a univariate dataset [Usage] • Select appropriate summary statistics based on the distributional properties of the data [Usage] • Compare classical and robust summary statistics and justify the choice for a given dataset [Assessment]
Readings : [**Devore2016**]	

Unit 2: Sample Spaces and Events (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Random experiments, outcomes, and sample spaces: finite, countable, and uncountable • Set-theoretic operations on events: union, intersection, complement, and De Morgan's laws • Sigma-algebras and measurable spaces as the foundation for rigorous probability • Borel sets and the Borel sigma-algebra on the real line	• Define sample spaces, events, and sigma-algebras for a given random experiment [Familiarity] • Apply set-theoretic operations to compute probabilities of compound events [Usage] • Construct appropriate sigma-algebras for measurable spaces arising in statistical problems [Assessment]
Readings : [**Ross2014**], [**Devore2016**]	

Unit 3: Probability Axioms and Properties (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Kolmogorov's three axioms of probability and their consequences • Derived properties: complement rule, addition rule, monotonicity, and continuity of probability • Classical, frequentist, and subjective (Bayesian) interpretations of probability • Counting methods: permutations, combinations, and the multiplication principle	• State Kolmogorov's axioms and derive fundamental probability properties [Familiarity] • Calculate probabilities of events using the addition rule and complement rule [Usage] • Apply counting methods to compute probabilities in finite sample spaces [Usage]
Readings : [**Ross2014**], [**Devore2016**]	

Unit 4: Conditional Probability and Independence (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Definition and interpretation of conditional probability P(A|B) and its properties • Bayes' theorem and the law of total probability: derivation and applications • Independence of events: pairwise and mutual independence • Conditional independence and its role in probabilistic graphical models	• Explain conditional probability and independence and their relationship [Familiarity] • Apply Bayes' theorem and the law of total probability to solve probability problems [Usage] • Analyze whether events are independent or conditionally independent in a given probability model [Assessment]
Readings : [**Ross2014**], [**Devore2016**]	

Unit 5: Discrete Random Variables and Distributions (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Probability mass functions (PMF) and cumulative distribution functions (CDF) for discrete random variables • Key discrete distributions: Bernoulli, Binomial, Geometric, Negative Binomial, Poisson, Hypergeometric • Properties of discrete distributions: mean, variance, skewness, and kurtosis • Poisson approximation to the Binomial and limiting distribution arguments	• Identify and describe the key discrete probability distributions and their parameters [Familiarity] • Calculate probabilities, means, and variances using PMFs of standard discrete distributions [Usage] • Select an appropriate discrete distribution to model a given random phenomenon and justify the choice [Assessment]
Readings : [**Ross2014**], [**Devore2016**]	

Unit 6: Continuous Random Variables and Distributions (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Probability density functions (PDF) and CDFs for continuous random variables • Key continuous distributions: Uniform, Normal, Exponential, Gamma, Beta, Chi-squared, t, F • The Normal distribution: properties, standard normal, and its central role in statistical inference • The exponential family of distributions: canonical form and sufficient statistics	• Describe the properties and parameters of key continuous probability distributions [Familiarity] • Calculate probabilities and quantiles for standard continuous distributions [Usage] • Identify distributions belonging to the exponential family and derive their sufficient statistics [Assessment]
Readings : [**Ross2014**], [**Devore2016**]	

Unit 7: Joint, Marginal, and Conditional Distributions (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Joint PMFs and PDFs for two or more random variables • Marginal and conditional distributions derived from joint distributions • Covariance, correlation, and their properties; independence implies zero covariance (converse not always true) • The bivariate normal distribution and its conditional distributions	• Derive marginal and conditional distributions from a given joint distribution [Usage] • Calculate covariance and correlation between two random variables [Usage] • Analyze the conditional structure of the bivariate normal distribution [Assessment]
Readings : [**Ross2014**], [**Devore2016**]	

Unit 8: Limit Theorems: LLN and CLT (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Weak law of large numbers: convergence in probability and its implications for estimation • Central limit theorem: statement, conditions, and role in justifying normal approximations • Applications of the CLT: normal approximation to the binomial and sampling distributions • Strong law of large numbers: almost sure convergence • The delta method: asymptotic distribution of smooth functions of estimators	• State the LLN and CLT and explain the conditions under which they hold [Familiarity] • Apply the CLT to derive normal approximations and sampling distributions [Usage] • Apply the delta method to derive asymptotic distributions of nonlinear estimators [Assessment]
Readings : [**Ross2014**], [**Devore2016**]	

Unit 9: Point Estimation (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Desirable properties: unbiasedness, consistency, efficiency, and sufficiency • Method of moments estimation: derivation and asymptotic properties • Maximum likelihood estimation: derivation, properties, and invariance principle • Cramer-Rao lower bound and the concept of Fisher information	• Describe the key properties of estimators and explain the trade-offs between them [Familiarity] • Derive method of moments and MLE estimators for standard distributions [Usage] • Evaluate the efficiency of an estimator using the Cramer-Rao lower bound [Assessment]
Readings : [**Devore2016**]	

Unit 10: Interval Estimation and Confidence Intervals (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Constructing confidence intervals using pivotal quantities and exact distributions • Correct interpretation of confidence intervals: coverage probability and common misconceptions • Large-sample confidence intervals based on asymptotic normality • Duality between confidence intervals and hypothesis tests	• Construct confidence intervals for means, proportions, and variances using exact and large-sample methods [Usage] • Interpret confidence intervals correctly and identify common misinterpretations [Usage] • Explain the duality between confidence intervals and hypothesis tests and use it to draw inferences [Assessment]
Readings : [**Devore2016**]	

Unit 11: Hypothesis Testing Foundations (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Neyman-Pearson framework: null/alternative hypotheses, rejection regions, Type I and II errors • p-values: definition, correct interpretation, and common misuse; power and sample size • Common parametric tests: z-test, t-test, F-test, chi-squared test • Neyman-Pearson lemma and uniformly most powerful tests	• Explain the logic of hypothesis testing, Type I and II errors, and the meaning of a p-value [Familiarity] • Apply standard parametric tests and interpret the results in context [Usage] • Derive the most powerful test for a simple hypothesis using the Neyman-Pearson lemma [Assessment]
Readings : [**Devore2016**]	

Unit 12: Bayesian Inference (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Bayesian framework: prior, likelihood, posterior, and the role of Bayes' theorem • Prior distributions: informative, non-informative, and conjugate priors • Posterior inference: point estimates, credible intervals, and posterior predictive distributions • Bayesian model comparison: Bayes factors and posterior model probabilities	• Explain the Bayesian approach to inference and contrast it with the frequentist approach [Familiarity] • Derive the posterior distribution for standard conjugate models [Usage] • Apply Bayes factors to compare statistical models and interpret the evidence [Assessment]
Readings : [**Ross2014**], [**Devore2016**]	

Unit 13: Simple Linear Regression (4 hours)	
Competences Expected: ABET-1	
Topics	**Learning Outcomes**
• Ordinary least squares estimation: derivation of coefficients and their properties • Inference for regression coefficients: t-tests, confidence intervals, and p-values • Coefficient of determination R-squared and analysis of variance decomposition • Gauss-Markov theorem: BLUE property of OLS under classical assumptions	• Fit a simple linear regression model and interpret the estimated coefficients [Usage] • Conduct hypothesis tests and construct confidence intervals for regression parameters [Usage] • Verify the Gauss-Markov assumptions and assess their consequences when violated [Assessment]
Readings : [**Devore2016**]	

8. WORKPLAN

8.1 Methodology

Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

8.2 Theory Sessions

The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

8.3 Practical Sessions

The practical sessions are held in class where a series of exercises and/or practical concepts are developed through problem solving, problem solving, specific exercises and/or in application contexts.

9. EVALUATION SYSTEM

********* EVALUATION MISSING ********

10. BASIC BIBLIOGRAPHY