

# SDSC4019: STOCHASTIC PROCESSES AND APPLICATIONS

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## Effective Term

Semester A 2024/25

## Part I Course Overview

### Course Title

Stochastic Processes and Applications

### Subject Code

SDSC - Data Science

### Course Number

4019

### Academic Unit

Data Science (DS)

### College/School

College of Computing (CC)

### Course Duration

One Semester

### Credit Units

3

### Level

B1, B2, B3, B4 - Bachelor's Degree

### Medium of Instruction

English

### Medium of Assessment

English

### Prerequisites

MA2506 Probability and Statistics or MA2510 Probability and Statistics

### Precursors

Nil

### Equivalent Courses

MA4546 Introduction to Stochastic Processes

### Exclusive Courses

Nil

## Part II Course Details

### Abstract

This course is an introduction to the probability models and stochastic processes (without measure theory) with the focus restricted to discrete time discrete state Markov chain and the applications to network science and data science. It also provides elementary numerical methods for solving real stochastic problems.

### Course Intended Learning Outcomes (CILOs)

CILOs		Weighting (if DEC-A1 DEC-A2 DEC-A3 app.)			
1	Explain concepts of stochastic processes, Markovian property, transition probability and transition matrix	30	x		
2	Describe and understand the theory of discrete time stationary Markov chain	30	x		
3	Perform basic numerical methods to compute limiting distributions and mean first passage time	20		x	
4	Apply basic knowledge of Markov chain to analyze some network and graph problems in data science.	20			x

#### A1: Attitude

Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

#### A2: Ability

Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

#### A3: Accomplishments

Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

### Learning and Teaching Activities (LTAs)

LTAs		Brief Description	CILO No.	Hours/week (if applicable)
1	Lectures	Learning through teaching is primarily based on lectures.	1, 2, 3, 4	39 hours in total
2	Take-home assignments	Learning through take-home assignments helps students understand basic concepts and theories of the stochastic processes and applications	1, 2, 3, 4	after-class

### Assessment Tasks / Activities (ATs)

ATs	CILO No.	Weighting (%)	Remarks (e.g. Parameter for GenAI use)
1	Test	1, 2, 4	15  Questions are designed for the first part of the course to see how well students have learned the concepts and theories of stochastic processes.  (10-30%)
2	Quiz	1, 2, 4	15  These are skills based assessment to help students understand concepts and basic methods in stochastic models.  (0-15%)
3	Formative take-home assignments	2, 3, 4	10  The assignments provide students chances to demonstrate their understanding of properties of stochastic process and their achievements on the applications.

**Continuous Assessment (%)**

40

**Examination (%)**

60

**Examination Duration (Hours)**

2

**Additional Information for ATs**

Note: To pass the course, apart from obtaining a minimum of 40% in the overall mark, a student must also obtain a minimum mark of 30% in both continuous assessment and examination components.

**Assessment Rubrics (AR)****Assessment Task**

Test

**Criterion**

Correct application of methods and correct calculations

**Excellent (A+, A, A-)**

High

**Good (B+, B, B-)**

Significant

**Fair (C+, C, C-)**

Moderate

**Marginal (D)**

Basic

**Failure (F)**

Not even reaching marginal levels

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**Assessment Task**

Quiz

**Criterion**

Skills of solving problems

**Excellent (A+, A, A-)**

High

**Good (B+, B, B-)**

Significant

**Fair (C+, C, C-)**

Moderate

**Marginal (D)**

Basic

**Failure (F)**

Not even reaching marginal levels

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**Assessment Task**

Formative take-home assignments

**Criterion**

Submission on time and independent work

**Excellent (A+, A, A-)**

High

**Good (B+, B, B-)**

Significant

**Fair (C+, C, C-)**

Moderate

**Marginal (D)**

Basic

**Failure (F)**

Not even reaching marginal levels

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**Assessment Task**

Examination

**Criterion**

Overall performance of understanding key concepts, applying right methods and performing correct computation

**Excellent (A+, A, A-)**

High

**Good (B+, B, B-)**

Significant

**Fair (C+, C, C-)**

Moderate

**Marginal (D)**

Basic

**Failure (F)**

Not even reaching marginal levels

**Part III Other Information****Keyword Syllabus**

- Review of Probability and basics of stochastic process: conditional probability and expectation, tower expectation theorem, Wald's equality; stationary, covariance, spectrum; Markov property, definitions of (discrete time) stopping time and martingale;
- Markov chain with a finite number of states:
  - i. stochastic matrix, transition matrix, multi-step transition probability; Chapman-Kolmogorov equation, master equation;
  - ii. limit distribution, stationary distribution, occupancy measure; communication class; reducible and irreducible, period of Markov chain;
  - iii. mean first passage time and distribution of exit location;
  - iv. random walk on 1D lattice; gambling ruin problem;
  - v. detailed balance, reversibility.
- Generating random variables, Sampling techniques, Variance reduction, Basics of Markov Chain Monte Carlo.
- Applications to some problems in practice such as for network science or data science

**Reading List****Compulsory Readings**

Title	
1	Lecture note
2	Introduction to Modeling and Analysis of Stochastic Systems, Second Edition, by V.G. Kulkarni, Springer, 2011

**Additional Readings**

Title	
1	Understanding Markov Chains: Examples and Applications, by Nicolas Privault, Springer Undergraduate Mathematics Series, 2013.

2	Introduction to Probability Models, Tenth Edition, by Sheldon M. Ross, Academic Press, 2009
3	An Introduction to Stochastic Modeling, Third Edition, by Howard Taylor and Samuel Karlin, Academic Press, 1998