University of Tehran
School of Electrical and Computer Engineering

Course	Queueing theory		
Course type, level, credit	Optional	Graduate	3 units
Field, Major	Computer Engineering	Software, Hardware, Information Technology	
Co-requisite(s)	-		
Prerequisite(s)	Basic Probability, Random Process		
Prerequisite by topic	Markov Chain, Markov Process, Transforms		
Goals	This course presents and develops methods from queueing theory in mathematical language and in sufficient depth so that the student may apply the methods to many modern computer and other engineering problems and conduct creative research.		
Outcome	This is an introductory course in queueing theory and performance modeling, with applications including but not limited to service operations (call centers) and computer system resource management (from datacenter to kernel level). The aim of the course is two-fold: 1. Build insights into best practices for designing service systems (How many service stations should I provision? What speed? How should I separate/prioritize customers based on their service requirements?) 2. Build a basic toolbox for analyzing queueing systems in particular and stochastic processes in general		
Topics	• Review of Stochastic Models Introduction to Queueing Systems : **Markovian Queueing Systems** Lecture 3 -4: Steady-state distribution for elementary queueing systems • Kendall's notation • M/M/1, M/M/m, M/M/m/m • Comparison of M/M/1 and M/M/m Lecture 5-6 : Analysis of waiting time distribution for elementary		

	queueing systems • Little's Law ($L = \lambda W$) • PASTA (Poisson Arrivals See Time Averages) • Laplace transform of waiting time in M/M/1 Lecture 7-8: Queueing Networks (I) • Open vs. Closed queueing networks • Operations Laws: Forced flow law, Bottleneck law • Asymptotic bounds for Closed Systems Lecture 9-10 : Queueing Networks (II) • Time reversibility • Burke's Theorem for M/M/1 • Tandem queues. Feed forward networks. • Jackson Networks. Solution via local balance/reversibility. • The BCMP Theorem. Kelly's symmetric policies. Lecture 11 : Queueing Networks (III) • Mean Value Analysis for closed Jackson networks • Method of Moments algorithm Lecture 12-13 : Method of phases and Matrix analytic method • Phase type and Coxian distributions • Solution of P h/P h/k and other QBD-type systems using Matrix analytic / Matrix geometric method **Beyond Markovian queueing systems**

	Lectures 14-15 : M/G/1/F CF S queue Renewal Theory. Renewal reward. Inspection paradox. • Mean waiting time in M/G/1 using Renewal reward. • M/G/1 waiting time distribution via Transforms. • Embedded Markov Chain Analysis, • M/G/1 busy period • priority systems Lectures 16-17: **Analysis of Scheduling policies for M/G/1 – Beyond First Come First Served** • Non-preemptive blind policies: FCFS, LCFS, Random-Order-of-Service • Preemptive blind policies: Preemptive Last Come First Served (PLCFS), Processor Sharing (PS), Foreground Background (FB) (or Least-Attained-Service LAS) • Non-preemtive size-based: Shortest Job First (SJF), static-priorities • Preemptive size-based: Shortest Remaining Processing Time (SRPT), Preemptive SJF
Required software	Matlab, Python, R
Assignments	6 homework
Projects	4 course project
Grading	Assignments: 20 % Course project 20% Attendance 5% Midterm exams: 25% Final exam: 30%
Textbook(s)	[1] Leonard Kleinrock, Queueing Systems. Volume 1: Theory, Wiley-Interscience, 1975. [2] Donald Gross, John F, Shortle, James M. Thompson, Carl M. Harris, Fundamentals of Queueing Theory, 4th Edition, Wiley-Interscience, 2008. [3] Giovanni Giambene, Queuing Theory and Telecommunications: Networks and Applications, Springer; 2nd ed. 2014. [4] Randolph Nelson, Probability, Stochastic Processes, and Queueing Theory: The Mathematics of Computer Performance

	Modeling, Springer, 1995.
Further readings	[1] Ronald W. Wolff, Stochastic Modeling and the Theory of Queues 1st Edition, Pearson, 1989. [2] Mor Harchol-Balter, Performance Modeling and Design of Computer Systems: Queueing Theory in Action, Cambridge University Press, 2013. [3] Hisashi Kobayashi, Brian L. Mark, System Modeling and Analysis: Foundations of System Performance Evaluation , Prentice Hall, 2009. [4] Kishor Trivedi, Probability and Statistics with Reliability, Queuing, and Computer Science Applications, John Wiley and Sons, New York, 2001. [5] D. Bertsekas and R. Gallager, Data Networks, 2nd Ed., Prentice Hall, 1992.