DEPARTMENT OF ELECTRICAL
AND
COMPUTER ENGINEERING

MCMASTER UNIVERSITY

GRADUATE COURSE DESCRIPTIONS

2011/2012

Electrical and Computer Engineering 704

Advanced Engineering Mathematics

Instructor: Dr. Y. Haddara
Office: ITB A223, ext. 24968
Email: yaser@mcmaster.ca

Prerequisites: MEng or MASc only

This course is on the survey of a number of mathematical methods of importance in engineering modeling and analysis. The course covers orthogonal function expansions, Fourier series and Fourier transforms, complex variables, functions, and complex integration, vector analysis, ordinary and partial differential equations, systems of differential equations, and numerical analysis.

Recommended textbooks:

1. Vladimir Mitin, Dmitri Romanov and Michael Polis, "Modern Advanced Mathematics for Engineers", Wiley-Interscience, 2001.

Grading based on the Project:

Mid-term test: 50%
Final 50%

Term 1

Electrical and Computer Engineering 707

Linear Systems

Instructor: Dr. T. Kirubarajan
Office: ITB-A112/A, ext. 24819
Email: **kiruba@mcmaster.ca**
Web: http://www.ece.mcmaster.ca/~kiruba/

Prerequisites: Engineering mathematics and basic linear algebra - - For M.Eng. and M.A.Sc. students ONLY

Course Summary: This course is intended as a first semester graduate course on linear systems theory, design and implementation with application to signal processing, communications, estimation and control. The objective is to present a comprehensive coverage of the basic tools needed by an electrical engineering graduate student specializing in the above areas.

Course Outline:

1. Linear spaces and linear operators
2. Mathematical descriptions of systems
3. State-space models, solutions and realizations
4. Controllability and observability of linear systems
5. Minimal realizations and coprime fractions
6. State feedback, state estimators and observers
7. Stability of linear and non-linear systems
8. Applications

Textbook/Reading: C.T. Chen, Linear System Theory and Design, Oxford University Press, 3rd Edition, 1999.

Additional Reading: W. Rugh, Linear System Theory Prentice Hall, Second Edition, 1996.
G. Strang, Linear Algebra and its Applications, Third Edition, 1988.

Grading:

Assignments and projects	30%
Mid-term	30%
Final exam	40%

Term: I

Electrical and Computer Engineering 705
PROBABILITY AND STOCHASTIC PROCESSES

Instructors: Dr. Jun Chen
ITB-A221, ext. 20163
Email: **junchen@mail.ece.mcmaster.ca**

Prerequisites: EE3TQ4 "Probability and Random Processes", or permission of the instructor

Course Outline:
(subject to change)

- Review: Probability and conditional probability, random variables, probability density function, probability mass function, cumulative distribution function, mean and variance, moment generating functions.
- Markov chain: Chapman-Kolmogorov equations, time reversibility, Markovian decision process.
- Poisson processes" exponential distribution, poisson process, generalization of the Poisson process
- Continuous-time Markov chain: birth and death processes, transition probability function, time reversibility
- Stationery processes: Brownian motion, white noise, Gaussian process, stationary process.
- Convergence concepts" convergence in mean square, convergence in probability, convergence in distribution

Textbook/Reading: Sheldon M. Ross, Introduction to Probability Models, 10th edition, Academic Press, 2009

Grading: Midterm test: 30%, Final Exam 70%

Term: II

Electrical and Computer Engineering 710

Engineering Optimization

Instructor: Dr. Tim Davidson,
ITB-A310, Ext. 27352.
e-mail: davidson@mcmaster.ca

Course web page: http://www.ece.mcmaster.ca/~davidson/ECE710

Recommended Text: Boyd and Vandenberghe, *Convex Optimization*, Cambridge University Press, Cambridge, 2004 (Book web page can be found at: http://www.stanford.edu/~boyd/cvxbook.html

Recommended Reading: Bertsekas, with Nedic and Ozdaglar, *Convex Analysis and Optimization*, Athena Scientific, Belmont, MA, 2003.
Nocedal and Wright, *Numerical Optimization*, Springer, New York, 1999.
Bertsekas, *Nonlinear Programming*, 2nd edition, Athena Scientific, Belmont, MA, 1999.
Gill, Murry and Wright, *Practical Optimization*, Academic Press, London, 1986.

Prerequisite: A solid background in linear algebra. Exposure to numerical computing, programming, optimization and engineering design will be helpful, but is not required.

Course Outline:
Principles of engineering optimization: modelling, formulation, solution and verification
A taxonomy of optimization problems and solution methods
Convex sets, convex functions and convex optimization
Duality
Unconstrained optimization
Constrained optimization, including interior point methods
Computational complexity and NP-completeness
Applications to engineering design

Lectures: There will be two lectures a week, each of about 90 minutes in duration.

Assessment:
Midterm Test: 20%
Final Exam: 35%
Design Project: 45%

Term: II

Electrical and Computer Engineering 712

Matrix Computations in Signal Processing

Instructor: Dr. J.P. Reilly

Web page: www.ece.mcmaster.ca/~reilly

Text: "Matrix Computations", 3rd edition, Golub and Van Loan, Johns Hopkins University Press

References: "Linear Algebra and Its Applications", 3rd edition, G. Strang
"Applied Numerical Linear Algebra", James W. Demmel

Course Outline:

1. Review of fundamental concepts of linear algebra
2. Covariance matrices and the Karhunen-Loeve expansion, applications
3. Singular value decomposition (svd), eigendecomposition (ed)
4. Gaussian elimination, condition number, and error analysis
5. Cholesky decomposition and applications
6. Linear Least Squares Estimation: background, normal equations, variance of solution, full-rank and rank-deficient solution using the svd.
7. The QR decomposition: Householder, Givens, fast Givens, and modified Gram-Schmit techniques, systolic arrays.
8. Solving least-squares using the QR decomposition: the full-rank and rank-deficient case.
9. Toeplitz systems

Grading: Assignments - 2 @ 20% each = 40%
Final Exam - 60%

Term: I

Electrical and Computer Engineering 718

Special Topics: High Performance Parallel Computing on Graphical Processing Units (GPU)

Instructor:

Dr. Alexandru Patriciu
Office: ITB-A308, ext. 20395
Email: **patriciu@mcmaster.ca**
Web: http://ece.mcmaster.ca/~patriciu

Prerequisites: For M.Eng. students

Course Objective: The course is an introduction in parallel algorithm design and programming techniques for massive arrays of processing units available on modern GPU. The course will introduce the students to GPU computing architectures provided by NDIDIA and ATI. This is a hands-on course, each student will complete a short project involving the design, implementation, testing, and performance evaluation of an algorithm on a GPU.

Course Outline:

1. NVIDIA CUDA architecture.
2. ATI Stream architecture.
3. GPU programming languages and techniques
   1. C extensions for CUDA
   2. OpenCL language for CUDA and ATI Stream Computing.
4. CUDA optimization issues.
5. Parallel algorithm design topics:
   1. Data decomposition
   2. Algorithm decomposition
   3. Parallel Reductions
6. Applications
   1. GPU accelerated linear systems of equations solvers.
   2. Fast nonlinear deformable tissue modeling using mesh-less methods.

Textbook/Reading:

1. NVIDIA CUDA Programming Guide; NVidia Inc.
2. NVIDIA CUDA Reference Guide; NVidia Inc.
3. ATI Stream Computing with OpenCL; ATI Inc.

Grading:

Each student will have to complete a project involving the design, implementation, testing, and evaluation of an algorithm on a GPU.

Term: II

Electrical and Computer Engineering 721

Digital Communications

Instructor:

Dr. Jian-Kang Zhang
Office: ITB-A217, ext. 27599
Email: **jkzhang@mail.ece.mcmaster.ca**
Web: http://ece.mcmaster.ca/fac_mems/jk.htm

Course Objective:

The objective of this course is to develop an understanding of the fundamental principles of the digital communication system, nd proficiency in applying the principles to the analysis and design of sophisticated digital communication systems.

Recommended Text: Upamanyu Madhow, Fundamentals of Digital Communication, Cambridge University Press, 2008

Course Outline:

1. Signal space
2. Modulation and demodulation
3. Channel equalization
4. Information theoretic limits on communications
5. Channel coding
6. MIMO communications

Grading:

- Two projects: each 20%
- Reading and Presentation: 20%
- Final Exam: 40%

Term: II

Electrical and Computer Engineering 723

Information Theory and Coding

Instructor:

Dr. Steve Hranilovic
e-mail: hranilovic@ece.mcmaster.ca
Web: http://www.ece.mcmaster.ca/~hranilovic

Objectives:

This is an introductory course in information theory and coding theory. As stated in the course text:

Information theory answers two fundamental questions in communication theory: what is the ultimate data compression? (Answer: the entropy H) And what is the ultimate transmission rate of communication? (Answer: the channel capacity C).

In later stages of the course, coding techniques will be discussed which approach these ultimate limits.

Required Text:

Thomas M. Cover and Joy A. Thomas, *Elements of Information Theory*, John Wiley & Sons, 1991, ISBN 0-471-06259-6.

Reference Text:

Stephen B. Wicker, *Error Control Systems for Digital Communication and Storage*, Prentice-Hall, 1995, ISBN 0-13-200809-2

Tentative Outline:

1. Entropy, relative entropy, mutual information, chain rules, data processing inequality, the asymptotic equipartition.
2. The Kraft inequality, Shannon-Fano codes, Huffman codes, arithmetic coding.
3. Discrete channels, random coding bound and converse, Gaussian channels, coloured Gaussian noise and optimal "water-pouring" power allocation.
4. Linear block codes and their properties, hard-decision coding, cyclic codes, convolutional codes, soft-decision decoding, Viterbi decoding algorithm.
5. Lattice codes, trellis coded modulation, coset-codes, multi-level codes/multi-stage decoding, iterative decoding.

Grading:

Mini-Project I – 15%, Mid-term – 30%
Mini-Project II – 15%, Final Exam – 40%

Term:

I

Electrical and Computer Engineering 727
Wireless Communication Networks

Instructor:
Dr. T. Todd
Office: ITB/A324, 529-7070 ext. 24343
Email: **todd@mcmaster.ca**
Course website: http://owl.mcmaster.ca/~todd/

Prerequisites: Comp Eng 4DK4 (Computer Communication Networks) or equivalent, ECE 739 (Resource Management and Performance Analysis In Wireless Communication Networks) or equivalent, CAS 736 (Analysis Of Stochastic Networks) or equivalent, or permission of the instructor. C programming experience required. Access to a Unix/Linux/Windows workstation and a C compiler.

Course Objective: This is an advanced course on wireless networking which focuses on various topics relating to cellular and wireless mesh networks. Much of the course will be run using student presentations and discussion, and each student will do a project containing a significant research component.

Textbook/Reading: Various books, papers, articles and lecture notes.

Grading:

Lab/Assignments	20%
Project	60%
Class Presentations and/or Final Exam	20%

Term: II

Electrical and Computer Engineering 728
Multimedia Communication

Instructors: Dr. S. Shirani
ITB-A320, ext. 27943
Email: **shirani@mcmaster.ca**

Course Goal: To introduce technologies involved in multimedia communications. Methods used to efficiently represent multimedia data (video, image, and audio), and deliver them over a variety of networks are discussed. State-of-the-art compression techniques will be introduced. Compression standards: H.26x, MPEG, and JPEG will be explained.

Course Content:

- Introduction
- Multimedia representation and compression
- Huffman coding
- Arithmetic coding
- Dictionary techniques
- Predictive coding
- Scalar quantization
- Vector quantization
- Differential coding
- Transform coding
- Subband coding
- Bit allocation
- Wavelet based compression
- Fractal coding
- Multimedia communication standards
- Visual compression standards JBIG, JPEG, MPEG 1,2,4 and H.261, H.263, H.264
- Audio/speech coding standards: MPEG audio coding, ITU-T speech coding

Textbook: Khalid Sayood, "Introduction to Data Compression", Third Edition, Morgan Kaufmann Publishers, 2005.

Reference Books:

R. Rao and et al., "Multimedia Communications Systems", Prentice Hall, 2002.

J. D. Gibson, "Multimedia Communications", Academic Press, 2001.

F. Kuo, W. Effelsberg, and J. J. Garcia-Luna-Aceves, "Multimedia Communications", Prentice Hall, 1998.

Brad Perry et al, "Content-Based Access to Multimedia Information From Technology Trends to State of the Art", Kluwer Academic Publishers, 1999

V.S. Subrahmanian, "Principles of Multimedia Database Systems", Morgan Kaufmann Publishers, Inc., 1998.

Grading: Homework: 35%, Project: 20%, Exam: 45%

Term: II

ECE729: Resource Management and Performance **Analysis for Wireless Communication Networks**

Dr. Dongmei Zhao
Department of Electrical and Computer Engineering
McMaster University
Office: ITB-A323, ext. 26127
Email: dzhao@mail.ece.mcmaster.ca

Course description:

This course focuses on resource management and performance analysis in transporting multimedia traffic in wireless communication networks. Topics include: traffic characteristics, connection admission control, packet scheduling, power distribution, and mobility and handoff management.
The objective of the course is to understand quality of service and resource management in wireless communication networks, study basic schemes for various resource management issues and performance analysis, and introduce recent development and open issues in wireless networks.

Course outline (subject to change):
1 Introduction
2 Review of elementary queuing theory
3 Traffic modeling
4 Traffic routing
5 Admission control
6 Access control
7 End-to-end performance analysis
8 Stochastic bounds and effective capacity
9 Feedback flow control (congestion control)
1
10 Power distribution
11 Handoff management
Textbook:
Course notes and a collection of journal papers from the current literature.
References:
1. M. Schwartz, "Broadband Integrated Networks", Prentice Hall, 1998.
2. D. Bertsekas and R. Gallager, "Data Networks", Prentice Hall, 1992.
3. T. S. Rappaport, "Wireless communications", Principles and Practice, 2nd Ed., Prentice
Hall, 2002.
4. G. Stuber, "Principles of Mobile Communication", 2nd Ed., Kluwer Academic Publisher,
2001.

5. D. Gross and C. M. Harris, “Queueing Theory”, 3rd Ed., John Wiley & Sons, 1998.

Prerequisites:

Probability and Random Process, Computer Communications Networks, and Wireless
Communication Networks.

Grading:

Assignments: 30%; Projects: 30%; Final exam: 40%.

Term 1

Electrical and Computer Engineering 732

Nonlinear Control Systems

Instructor: Dr. Shahin Sirouspour, ITB-A319, Ext. 26238
sirouspour@ece.mcmaster.ca

Objective: To develop an understanding of the state-of-the-art in applied analysis and synthesis of nonlinear control systems with an emphasis on robotic control systems. Topics to be covered range from phase-plane analysis, Lyapunov and input-output stability, to feedback linearization and backstepping control.

Lectures: 3 hours/week

Recommended Text: Instructor's lecture notes.

Recommended Reading:
- M. Vidyasagar, *Nonlinear Systems Analysis*, SIAM, 2002.
- S. Sastry, *Nonlinear Systems, Analysis, Stability, and Control*, Springer, 1999.
- M. Krstic, et al., *Nonlinear and Adaptive Control Design*, John Wiley, 1995.
- J.-J. E. Slotine and W. Li, *Applied Nonlinear Control*, Prentice Hall, 1991.

Prerequisite: An undergraduate course in control systems (e.g. EE4CL4 or MECH ENG 4R03) and a solid background in mathematical analysis.

Course Content:

- Linear vs. Nonlinear Control, an introduction
- Phase Plane Analysis
- Describing Functions
- Lyapunov Stability
  - Stability of Linear Systems
  - Linearization and Local Stability
  - Lyapunov's Direct Method
  - LaSalle's Invariance Principle
  - Instability Theorems

- Input-output Stability
  - L_p spaces and their Extension
  - Small Gain Theorem
  - Passivity
  - Positive Real and Strictly Positive Real Transfer Functions
  - The Lur'e problem
  - Circle and Popov Criteria
- Feedback Linearization
  - Vector fields, Lie Brackets, and Lie Algebra
  - Input-State Linearization
  - Input-Output Linearization
  - Zero Dynamics
  - Feedback Linearization for MIMO Systems
- Robust & Adaptive Nonlinear Control
  - Sliding Mode Control
  - Adaptive Control of Linear Systems
  - Adaptive Control of Nonlinear Systems
- Linear Parameterization Model
- Prediction-Error-Based Estimation Methods
- The Least-Squares Estimator
  - Composite Adaptation
  - Adaptive Backstepping Control
- Application Examples

Evaluation:

Final Exam: 40%
Course Project: 40%
Assignments: 20%

Term: I

Electrical and Computer Engineering 734

Advanced Topics in Multimedia Coding and Communications

Instructor: Prof. Sorina Dumitrescu
ITB-A317, X26486, dumitrs@mcmaster.ca

Prerequisites: Multimedia Communications ECE728, or Information Theory and Coding ECE723, or permission from the instructor.

The aim of this course is to familiarize the students with recent results in several modern research topics in multimedia coding and communications. The four main topics (joint source-channel coding/decoding, multiple description coding, distributed source coding, network coding) are primarily motivated by new challenges in multimedia transmission over modern communications networks. The presentation will include the theoretical foundations (asymptotic rate-distortion results) as well as practical aspects (algorithms for optimal code design, decoding strategies), applications, and open problems.

Research in joint source-channel coding/decoding (in the sense we consider here) is motivated by the idea that practical constraints in communications systems (eg. constraints in delay and/or complexity) may rend suboptimal the separate design of compression algorithm (source code) and error protection scheme (channel code), thus leading to severe degradation in performance. Therefore joint approaches in the design of the two components have the potential of improving the system's performance. Multiple description coding (MDC) refers to generating several separate descriptions of a common source, such that it can be reconstructed to some fidelity from any subset of received descriptions. By allowing a graceful degradation of the signal fidelity in adverse channel conditions, MDC becomes an important paradigm for reliable multimedia transmission over packet lossy networks. Distributed source coding refers to separate compression of multiple correlated sources. It finds applications in sensor networks, but also in other scenarios like layered coding for video streaming. Network coding has at its core the principle of allowing each intermediate network node to encode the data it receives. This leads to an increase of the information flow through the network versus the case when nodes perform only routing.

Intended Outline:

1) Joint source-channel coding/decoding – a) Optimal index assignment (IA) in quantization. Combinatorial considerations. Affine IA. Joint design of quantizer and IA. b) Decoding strategies which exploit the redundancy left in the source code. MAP sequence and MAP symbol estimation algorithms for joint source-channel decoding (JSCD) of variable length codes. Optimal and suboptimal

techniques for JSCD complexity reduction. Applications in image and video coding.

2) Multiple description coding (MDC) – Rate-distortion bounds on MDC performance. Generalized Lloyd algorithm for optimal MD scalar quantization; the index assignment problem. MD lattice vector quantization. MDC by unequal erasure protection of scalable codestreams; rate-distortion optimization algorithms. MD with correlated transforms. Other MD techniques in image coding. Multi-resolution source codes and the problem of successive refinement of information.
3) Distributed source coding (DSC) – Slepian-Wolf and Wyner-Ziv Theorems. Practical design of DSC with DISCUS. Applications in sensor networks. Wyner-Ziv video coding.
4) Network coding – The concept of network information flow. Max-flow Min-cut Theorem and asymptotic optimality of linear network codes for single information source. Max-flow bounds in the case of multiple information sources. Linear network codes for multiple sources. Practical design of network source coding.

Grading: Assignments: $4 \times 15\% = 60\%$; Project: 40%.

References: The following bibliographical list will be complemented with other recent publications in IEEE Transactions on Information Theory, Communications, Image Processing, Multimedia and others.

[1] A. Kurtenbach, P. Wintz, "Quantizing for noisy channels" *IEEE Transactions on Communications,* vol. 17, no. 2, pp. 291 - 302, Apr. 1969.

[2] K. Zeger, A. Gersho, "Pseudo-Gray coding" *IEEE Transactions on Communications*, vol. 38, no. 12, pp. 2147 - 2158, Dec. 1990.

[3] N. Farvardin and V. Vaishampayan, "On the Performance and Complexity of Channel Optimized Vector Quantizers," IEEE Trans. Inform. Theory, Vol. 37, pp. 155-160, Jan. 1991.

[4] K. Zeger, A. Mehes, "Binary lattice vector quantization with linear block codes and affine index assignments", *IEEE Transactions on Information Theory*, vol. 44, no. 1, pp. 79 - 94, Jan. 1998.

[5] K. Sayood and J. C. Borkenhagen, "Use of Residual Redundancy in the Design of Joint Source/Channel Coders", *IEEE Trans. Comm.*, vol. 39, no. 6, pp. 835-846, June 1991.

[6] N. Phamdo and N. Farvardin, "Optimal Detection of Discrete Markov Sources over Discrete Memoryless Channels - Applications to Combined Source-Channel Coding", *IEEE Trans. Inf. Th.*, vol. 40, no.1, pp. 186-193, Jan. 1994.

[7] M. Park and D. J. Miller, "Joint source-channel decoding for variable-length encoded data by exact and approximated MAP sequence estimation", *IEEE Trans. Comm.*, vol. 48, no. 1, pp. 1-6, Jan. 2000.

[8] R. Bauer and J. Hagenauer, "Symbol-by-symbol MAP Decoding of Variable Length Codes", *Proc. 3rd ITG Conf. Source Channel Coding*, Munich, Germany, pp. 111-116, Jan. 2000.

[9] J. Hagenauer and N. Gortz, "The Turbo Principle in Joint Source-Channel Coding", *IEEE ITW 2003*, pp. 275-278, April 2003.

[10] A. A. El Gamal, and T. M. Cover, "Achievable Rates for Multiple Descriptions", *IEEE Transactions on Information Theory*, vol. 28, no. 6, pp. 851-857, Nov. 1982.

[11] L. Ozarow, "On a source coding problem with two channels and three receivers", *Bell Syst. Tech. J.*, vol. 59, pp. 1909-1921, Dec. 1980.

[12] W.H.R., Equitz, T.M., Cover, "Successive refinement of information", *IEEE Transactions on Information Theory*, vol. 37, no. 2, pp. 269 - 275, March 1991.

[13] V. A. Vaishampayan, "Design of Multiple Description Scalar Quantizers", *IEEE Transactions on Information Theory*, vol. 39, no. 3, pp. 821-834, May 1993.

[14] V. K. Goyal, "Multiple description coding: compression meets the network", *IEEE Signal Processing Magazine*, vol. 18, pp. 74-93, Sept. 2001.

[15] V. A. Vaishampayan, N. J. A. Sloane, and S. Servetto, "Multiple-Description vector quantization with lattice codebooks: design and analysis", *IEEE Transactions on Information Theory*, vol. 47, no. 5, pp. 1718-1734, July 2001.

[16] R. Hamzaoui, V. Stankovic, and Z. Xiong, "Forward error control for packet loss and corruption", in *Multimedia over IP and Wireless Networks*, Eds: M. Van Der Schaar, P. A. Chou, Academic Press, Elsevier, 2007.

[17] D. Slepian and J.K. Wolf, Noiseless coding of correlated information sources, IEEE Trans. Inform. Theory, vol. IT-19, pp. 471-480, July 1973.

[18] A.D. Wyner and J. Ziv, "The rate distortion function for source coding with side information at the decoder," IEEE Trans. Inform. Theory, vol. IT-22, pp.1-10, January 1976.

[19] S.S Pradhan, J. Kusuma, and K. Ramchandran, Distributed compression in a dense microsensor network", *IEEE Signal Processing Magazine*, vol. 19, pp. 51-60, Mar. 2002.

[20] S.S Pradhan and K. Ramchandran, Distributed source coding using syndromes (DISCUS): Design and construction", *IEEE Trans. Inform. Th.*, vol. 49, pp. 626-643, Mar. 2003.

[21] Z. Xiong, A. Liveris, and S. Cheng, \Distributed source coding for sensor networks," *IEEE Signal Processing Magazine*, vol. 21, pp. 80-94, Sept. 2004.

[22] B. Girod, A. Aaron, S. Rane, D. Rebollo-Monedero, "Distributed Video Coding," *Proceedings of the IEEE*, vol. 93, no. 1, pp. 71-83, Jan. 2005.

[23] Q. Xu and Z. Xiong, \Layered Wyner-Ziv video coding," *IEEE Trans. Image Processing*, vol. 15, pp. 3791-3803, Dec. 2006.

[24] R. Ahlswede, N. Cai, S.-Y. R. Li, and R. W. Yeung, "Network Information Flow", *IEEE Transactions on Information Theory*, IT-46, pp. 1204-1216, July 2000.
[25] S.-Y. R. Li, R. W. Yeung, and N. Cai. Linear network coding. IEEE Transactions on Information Theory, February, 2003
[26] R. W. Yeung, S. -Y. R. Li, N. Cai, and Z. Zhang, Network Coding Theory, Foundation and Trends in Communications and Information Theory , vol. 2, nos. 4 and 5, pp. 241 -381, 2005.
[27] M. Fleming, Q. Zhao, M. Effros, "Network vector quantization", *IEEE Transactions on Information Theory*, vol. 50, no. 8, pp. 1584-1604, Aug. 2004.

Term: II

Electrical and Computer Engineering 735

NETWORK INFORMATION THEORY

Instructor: Prof. Jun Chen
ITB-A221, X20163, junchen@mail.ece.mcmaster.ca

Prerequisites: Undergraduate courses in linear algebra, signals and systems, probability and digital communication. Prior Exposure to information theory is preferred, but not required.

General Description: Network information theory deals with the fundamental limits on information flow in networks and optimal coding techniques and protocols that achieve these limits. It extends Shannon's point-to-point information theory to networks with multiple sources and destinations. Although a complete theory is yet to be developed, several beautiful results and techniques have been developed over the past forty years with applications in wireless communication, the internet, and other networked systems. This course aims to provide a broad coverage of key results, techniques, and open problems in network information theory.

Textbook: Abbas El Gamal and Young-Han Kim, Lecture Notes on Network Information Theory, {online} http://circuit.ucsd.edu/_yhk/Init.html.

Tentative Outline (Time Permitting:

1. Entropy, Mutual Information, and Typicality
2. Point-to-Point Communication
3. Multiple Access Channels
4. Degraded Broadcast Channels
5. Interference Channels
6. Channels with State
7. General Broadcast Channels
8. Distributed Lossless Source Coding
9. Source Coding with Side Information
10. Distributed Lossy Source Coding
11. Multiple Descriptions
12. Joint Source-Channel Coding

Grading: Lecture Report 50%, Presentation 50%, Project (optional) 20%

Term: II

Electrical and Computer Engineering 740

Semiconductor Device Theory and Modeling

Instructor:	Dr. M. Jamal Deen CRL-226, X27137, email: jamal@mcmaster.ca
Office Hours:	One hour immediately after each class or by appointment
Lectures:	3 hours per week
Text:	D.A. Neaman, *Semiconductor Physics and Devices*, 3rd Ed., McGraw-Hill (2002).

Course Outline:

1. Review of semiconductor fundamentals and technology
2. Simple semiconductor homo- and hetero-junction devices and passive devices theory of operation; modeling; parameter extraction
3. Detailed study of MOS capacitors and transistors operation; modeling; parameter extraction; scaling issues; small dimension, high-current and high-voltage effects.
4. Detailed study of modern bipolar junction transistors operation; modeling; parameter extraction; scaling issues; small dimension, high-current and high-voltage effects
5. Applications of silicon devices - detectors, sensors, etc.

Course Description: This course provides a fundamental in-depth knowledge of the theory of operation, modeling, parameter extraction, scaling issues, and higher order effects of active and passive semiconductor devices that are used in mainstream semiconductor technology. There will be a comprehensive review of the latest models for the devices that are valid out to very high frequencies and the use of physical device modeling/CAD tools. A review of the latest device technologies will be presented. The course will be a prerequisite to the other applied courses in microelectronics.

Project Description: The project can be a detailed review or investigation of a specific part of the course. Examples are SiGe HBTs or deep submicron MOSFETs modeling issues for RF applications; transistor design for low noise applications; comparison of ac or noise models used for HF modeling of a specific device; device parameter extraction techniques; modeling issues of passive components in silicon technology at microwave frequencies etc.

Grading:

Assignments	25%	Semester exam	15%
Project	30%	Final Exam	30%

References:

IEEE Transactions on Electron Devices, Solid-State Electronics, Journal of Applied Physics etc.

ECS, ICMTS, IEDM, ESSDERC, DRC Proceedings.

TMA MEDICI and SILVACO PISCES, BSIM, HSPICE, SPECTRE RF Simulators and manuals.

Y.P. Tsividis - Operation and Modelling of the MOS Transistor, 2nd Ed., McGraw Hill (1999), (TK 7871.99.M44.T77)

D.J. Roulston - Bipolar Semiconductor Devices, McGraw Hill (1990), TK 7871.86.R68.

D. Ferry, L. Akers and E. Greeneich - Ultra Large Scale Integrated Microelectronics, Prentice Hall (1988).

C.T. Sah - Fundamentals of Solid-State Electronics, World Scientific, Singapore (1991), TK 7871.85.S23

M. Shur - Physics of Semiconductor Devices, Prentice Hall (1990), QC 611.S563.

S.M. Sze - Physics of Semiconductor Devices, John Wiley & Sons (1981), TK 7871.85.S988.

S.M. Sze (Ed.) - Modern Semiconductor Device Physics, John Wiley & Sons (1998), QC 611.M674.

M.S. Tyagi - Introduction to Semiconductor Materials and Devices, John Wiley (1991), TK7871.85.T93.

S. Wang - Fundamentals of Semiconductor Theory and Device Physics, Prentice Hall (1989), QC 611.W32.

R. Warner & B. Grung - Semiconductor Device Electronics, Holt Rinehart & Winston (1991), ISBN 0-03-009559-X.

Term: I

Electrical and Computer Engineering 741
Analog Integrated Circuits

Instructor: Dr. Jamal Deen
Office: ITB/104, ext. 27137
Email: **jamal@mcmaster.ca**

Course Description: This course provides a fundamental, in-depth knowledge of the operation, analysis, modeling, design and layout of CMOS analog integrated circuits. There will be a comprehensive review of the latest analog integrated circuits and detailed analyses of their operation. In addition, the course will have special emphasis on the theory, design and performance of low-voltage, low-power analog integrated circuits.

Project Description: The project will be the complete design and analysis of a state-of-the art low-voltage analog integrated circuit. The project is a detailed discussion or investigation of a specific part of the course. There will be a presentation in class and a written report .

- Pick one topic and research in detail
- Why important and uses/applications
- Review of architectures and detailed analysis
- Comparisons and simulations
- Discussions-attractive features and limitations – performance characteristics
- Other design issues

Course Outline:

- Review of state-of-art CMOS IC technology
- Mosfet device review – Subthreshold operation
- Mismatch analysis
- Models for IC active and passive devices and CAD tools
- Noise in integrated circuits
- Analysis of simple amplifiers-differential cascade, high-gain, current and output
- Examples of analog IC blocks –I sources and mirrors, active loads, V sources, comparators, …
- Operational amplifiers characteristics, analyses, and circuit design examples. Low-power co-amps
- Frequency response of integrated circuits
- Examples and applications of analog integrated circuits
- Examples of state-of-the-art LP circuits for biomedical applications

References:

P. Allen and D. Holberg - CMOS Analog Circuit Design, 2nd Ed., Oxford University Press, 2002.

P.R. Gray, P.J. Hurst, S.H. Lewis & R.G. Meyer - Analysis & Design of Analog ICs, John Wiley & Sons, 4th Ed, 2001.

A.B. Grebene - Analog Integrated Circuit Design, Van Nostrand Reinhold, NY, 1972.

A.B. Grebene - Bipolar and MOS Analog Integrated Circuit Design, Wiley, NY, 1984.

G.M. Glasford - Analog Electronic Circuits, Prentice Hall 1986.

R. Gregorian and G.C. Temes - Analog MOS Integrated Circuits for Signal Processing, Wiley Interscience, 1986.

M.R. Haskard and I.C. May - Analog VLSI Design - nMOS and CMOS, Prentice Hall, 1988.

M.J. Jacob - Analog Integrated Circuit Applications, Prentice Hall, N.J., 2000.

D.A. Johns and K. Martin - Analog Integrated Circuit Design, John Wiley and Sons, 1997.

K.R. Laker and W.M.C. Sansen - Design of Analog Integrated Circuits and Systems, McGraw Hill, 1994.

B. Razavi - Design of Analog CMOS Integrated Circuits, McGraw Hill, 2001.

B. Razavi - Design of Integrated Circuits for Optical Communications, McGraw Hill, 2003.

Y. Tsividis - Mixed Analog-Digital VLSI Devices and Technology, McGraw Hill, 1996.

Conference Proceedings – CICC, ISCAS, ISSCC, ESSCIRC Proceedings. Journals – SSC Analog ICs and SP Texts (e.G.) by DJ Roulston, M. Shur, S.M. Sze, Y. Tsividis, M.S. Tyagi, S. Wang and R. Warner and Grung) on semiconductor devices, device physics, modeling of MOS and bipolar transistors and device modeling.

Grading:

Assignments	30%
Presentations	30%
Project	40%

Term: II

Electrical and Computer Engineering 744

System-on-a-Chip (SOC) Design and Test: Part 1 - Methods

Instructor:
Dr. Nicola Nicolici
Room: ITB-A210, Phone: 905-525-9140 ext. 27598
Email: nicola@ece.mcmaster.ca

Course Description: This course covers design methodologies that meet the challenge of the global shift from chip-based products to those which implement complete systems on a single chip. The topics include overview of embedded cores and in-depth coverage of digital system testing. Understanding of hardware description languages is recommended.

Topics: Verilog tutorial, SOC overview, system customization (processors, memories, ...), testing process, economics, quality, and test equipment, automatic test pattern generation, delay fault testing, design for testability (DFT), built-in self-test (BIST), P1500 and embedded core test.

Grading: Homework 30% ; Project 70%
(subject to change; exact details will be given in the organizational meeting at the beginning of the term);

Homework: Reading research papers and solving small sets of problems.

Project: The project consists of designing for testability an embedded core, which can be reused in a custom application-specific SOC. Verilog will be used as hardware description language and the project proposals will be discussed in the first month of the course.

Selected References:

1. Essentials of Electronic Testing, by M. Bushnell and V. Agrawal (Kluwer 2000)
2. Digital Systems Testing and Testable Design, by M. Abramovici et. al (IEEE Press 1995)
3. IEEE Transactions on Computers, CAD, VLSI + Design and Test of Computers, Micro, Computer
4. IEEE/ACM Conference Proceedings - DAC, DATE, ICCAD, ITC, VTS

Term: I

Electrical and Computer Engineering 745

System-on-a-Chip (SOC) Design and Test: Part 2 - Algorithms

Instructor:

Dr. Nicola Nicolici
Room: ITB-A210, Phone: 905-525-9140 ext. 27598
Email: nicola@ece.mcmaster.ca

Course Description:

This course offers fundamental algorithms that are part of the computer-aided design (CAD) tools which are essential to the future of SOC design. The topics include architectural and logic level design automation algorithms, as well as computer-aided verification and test.

Topics:

SOC and CAD overview, computational complexity and heuristics, architectural synthesis, two/multilevel sequential logic synthesis, timing analysis, technology mapping.

Grading:

Homework 30% Project 70%
(subject to change; exact details will be given in the organizational meeting at the beginning of the term);

Homework:

Reading research papers and solving small sets of problems.

Project:

The project consists of analysis and implementation of design automation algorithms at a selected level of abstraction (system, algorithmic, gate, physical). Recommended implementation languages are C/C++. Possible integration and/or interface to state-of-the-art third party CAD tools is encouraged using hardware description languages such as VHDL/Verilog.

Selected References:

1. S. Gerez - Algorithms for VLSI Design Automation (John Wiley 1998)
2. G. de Micheli - Synthesis and Optimization of Digital Circuits (McGraw Hill 1994)
3. IEEE Transactions on Computers, CAD, VLSI + Design and Test of Computers, Micro, Computer
4. IEEE/ACM Conference Proceedings - DAC, DATE, ICCAD, ITC, VTS

Term:

II

Electrical and Computer Engineering 746

Analysis and Design of RF ICs for Communications

Instructor: Dr. C.H. (James) Chen

Texts: Bosco Leung, *VLSI for Wireless Communications*, Prentice-Hall, TK7874.75.L48, 2002

Reference Texts:

1. B. Razavi, *RF Microelectronics*, Prentice-Hall Inc., 1998.
2. T.H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*, Cambridge University Press, 1998.
3. G. Gonzalez, *Microwave Transistor Amplifiers: Analysis and Design*, 2nd ed., Prentice-Hall Inc., 1997.
4. Lawrence P. Huelsman, *Active and Passive Analog Filter Design: An Introduction*, McGraw-Hill, 1993.
5. D.A. Johns and K. Martin, *Analog Integrated Circuit Design*, John Wiley & Sons, Inc., New York, 1997.
6. P.E. Allan and D.R. Holberg, *CMOS Analog Circuit Design*, 2nd ed., Oxford Press, 2002.
7. B. Razavi, *Design of Analog CMOS Integrated Circuits*, McGraw-Hill, 2001.
8. Clarke and Hess, *Communication Circuits: Analysis and Design*, Krieger, Reprint, 1994.
9. H.L. Krauss, C.W. Bostian, F.H. Raab, *Solid State Radio Engineering*, Wiley, 1980.

Course Description: This course provides a fundamental and in-depth knowledge of the analysis and design of radio-frequency (RF) integrated circuits (IC) in the CMOS technology for wireless communications. The topics include the modelling of active and passive components for AC and noise analysis, design examples of amplifiers, filters, oscillators, PLL and frequency synthesizers. Circuit performance will be evaluated by both hand calculations and computer simulations. A good understanding of circuit analysis and CAD tools (e.g., HSPICE or SpectreRF) is required.

Course Outline:

1. Passive and active components at RF
2. Design of low-noise amplifiers
3. Active and passive filters
4. Operation and design of mixers
5. Oscillators
6. Phase locked loop
7. Frequency synthesizers

Project: Project will be the design and detailed analysis, including both hand calculations and computer simulation of an RF integrated circuit for a specific purpose/application. Possible projects will be discussed at the beginning of class.

Grading: Assignments - 50%
Term Project - 50%

Term: II

Electrical and Computer Engineering 747

Polymer and Organic Semiconductors

Instructor: Dr. Yaser M. Haddara

Text: Course notes and journal papers.

Description: The course will explore electronic properties of polymer and organic semiconducting materials. In particular, we will study material structure, charge carriers, electronic transport, the effect of doping, device behaviour, and fabrication issues.

Format: The course will be divided in two parts. The first part will be conventional lecture-style and will cover the basic concepts. The second half of the course will be made up of presentations by the students on a topic related to the material. The presentations must be based on research papers prepared by the students and circulated to other students in the class, and will form part of the material of the course.

Grading:

Written project (due Wednesday October 25)	40%
Presentation	30%
Participation	10%
Final exam (in-class)	20%

- Each student must circulate the presentation slides in hard-copy or electronically by the Friday preceding his/her presentation.
- Participation will be assessed on asking questions of other student presenters.

Lectures: tba

Term: I

Electromagnetic Scattering from Random Media 748

Instructor:

Dr. Timothy Field
Office: ITB_XXX, ext. xxx
Email: **xx@mcmaster.ca**
Web: http://ece.mcmaster.ca/

Course format:

Advanced graduate level course based on topics from the instructor's recent monograph. Scheduled weekly classes cover core topics (Part I) and also provide opportunity for consultation on selected special topics (Parts II & III) to be agreed between student and instructor.

Required Text:

Electromagnetic Scattering from Random Media[1]
Timothy R. Field
Oxford International Series of Monographs on Physics, 144
ISBN13: 978-0-19-857077-6, ISBN10: 0-19-857077-5

Perspective:

The course aims to develop the student's understanding of the dynamical theory of scattering from random media, from a first principles perspective.

The principal themes are to characterize the time evolution of the scattered field in terms of stochastic differential equations, and to illustrate this framework in simulation and experimental data analysis. The physical models contain all correlation information and higher order statistics, which enables radar and laser scattering experiments to be interpreted. An emphasis is placed on the statistical character of the instantaneous fluctuations, as opposed to ensemble average properties. This leads to various means for detection, which have important consequences in radar signal processing and statistical optics. There are also significant connections with ideas in mathematical finance that can be applied to physics problems in which non-Gaussian noise processes play an essential role.

This course promotes a significant advance in this field, and should prove valuable to advanced postgraduate and postdoctoral researchers in engineering, physics and mathematics.

[1] Limited number of copies available from the author.

List of Topics: **Core topics to be covered from Part I and selected topics from Parts II & III**

I. STOCHASTIC CALCULUS

1. Heat equation and Brownian motion
2. Ito calculus
3. Stochastic differential geometry
4. Examples of stochastic differential equations

II: SCATTERING DYNAMICS

5. Diffusion models of scattering
6. Rayleigh scattering
7. Population dynamics
8. Dynamics of K-scattering
9. Models of weak scattering
10. Scattering from general populations

III: SIMULATION AND EXPERIMENT

11. Simulation of K-scattering
12. Experimental tests
13. Non-linear dynamics of sea clutter
14. Observability of scattering cross-section

Additional specialized topics of relevance

A. Stability and infinite divisibility
B. Ito versus Stratonovich stochastic integrals
C. Filtrations, conditional probability and Markov property
D. Girsanov's theorem
E. Partition function solution to BDI model
F. Summary of K-scattering
G. Iterative solution for vector processes
H. Open problems
I. Suggested further reading

In addition students may be advised to consult pertinent research papers cited in the text according to their chosen topics.

Evaluation Method: Written examination (core) 50% / simulation project (special topics) 50%.

Prerequisites: Strong background in theory of stochastic processes is essential.

Term 2

Electrical and Computer Engineering 753
Modern Antennas in Wireless Telecommunications

Instructor: Dr. Natalia Nikolova
ITB-A220, ext. 27140
Email: **talia@mcmaster.ca**

Course Website: http://www.ece.mcmaster.ca/faculty/nikolova/antennas.htm

Prerequisites: *Theory and Applications in Electromagnetics* (EE3FI4) or Electromagnetics – Part I (**EE2FH3**), and Electromagnetics – Part II (**EE3FK4**)

Course Description: This course provides fundamental knowledge in the theory and practice of antenna design and deployment in modern wireless telecommunication systems. The theory of electromagnetic radiation is introduced and the fundamental antenna parameters are explained. Basic antenna measurement techniques are introduced and practiced in a 6-hour laboratory session. The principles of analysis and design of antenna arrays are discussed. Special attention is paid to antennas used in mobile (cellular, satellite) communications. The fundamental limitations of electrically small antennas as well as the principles of smart antennas are briefly introduced through seminar sessions.

Courseware and text:

1. Lecture Notes (distributed in class and available for download)
2. C.A. Balanis, *Antenna Theory*, 3rd ed., Wiley-Interscience, New York, 2005.

Additional sources:

3. Elsherbeni and Inman, *Antenna Design & Visualization Using MATLAB*, Scitech, 2006.
4. J. D. Kraus and R. J. Marhefka, *Antennas (for all Applications)*, 3rd ed., McGraw-Hill, 2002. (the previous editions authored by Kraus only are fine, too).
5. W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design*, 2nd ed., Wiley, 1998.
6. R. S. Elliot, *Antenna Theory and Design*, A Classical Reissue, IEEE Press, 2003.

On antennas and propagation:

7. R. E. Collin, *Antennas and Radiowave Propagation*, McGraw-Hill, Inc. 1985.
8. K. Siwiak, *Radiowave Propagation and Antennas for Personal Communications*, 2nd ed., Artech House, Inc., Norwood, MA, 1998.

9. J. Doble, *Introduction to Radio Propagation for Fixed and Mobile Communications*, Artech House, Inc., Norwood, MA, 1996.

On smart antennas:

10. T. K. Sarkar, M. C. Wicks, M. Salazar-Palma, R. J. Bonneau, *Smart Antennas*, Wiley, 2003.

Course Outline:

1. Introduction into antenna theory and practice.
2. Radiation integrals and auxiliary potential functions; basic EM theorems in antenna problems.
3. Fundamental antenna parameters.
4. Antenna measurements.
5. Infinitesimal dipole; wire and loop radiating elements.
6. Wire antennas – dipoles, monopoles, Yagi-Uda array.
7. Arrays – analysis and design.
8. Printed antennas.
9. Reflector antennas.
10. Horn antennas.

Seminars:

11. Smart antennas and signal processing antennas.
12. Fundamental limitations of electrically small antennas.

Lectures: There will be one lecture per week, of about 3 hours in duration.

Grading:

Laboratory	20 %
Weekly Assignments	40 %
Project	40 %

Term: II

Policy reminder:

Academic dishonesty consists of misrepresentation by deception or by other fraudulent means and can result in serious consequences, e.g., the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various kinds of academic dishonesty please refer to the Academic Integrity Policy, specifically Appendix 3, located at http://www.mcmaster.ca/senate/academic/ac_integrity.htm

The following illustrates only three forms of academic dishonesty:

- Plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
- Improper collaboration in group work.
- Copying or using unauthorized aids in tests and examinations.

Electrical and Computer Engineering 754

Modeling and Simulation of Photonic Devices and Circuits I (Passive Devices and Circuits)

Instructor: Dr. Wei-Ping Huang
CRL-211, ext. 27696
Email: huang@ece.eng.mcmaster.ca

Prerequisites: Electromagnetic Fields (3FI4)

Course Description: Photonic devices and circuits are key components used for lightwave generation, amplification, transmission and detection in communication systems and networks. Photonic devices and circuits that utilize primarily photons, in conjunction with electrons can offer the tremendous bandwidth which is the key to a variety of applications, especially broadband communication systems and networks. This course will focus on the modelling of passive device physics through numerical approaches, the simulation of device terminal performances through mixed analytical and numerical methods and the extraction of device behaviour models. This course will also cover circuit level simulation for a variety of monolithically or hybrid integrated photonic circuits constructed on those devices.

Course Outline:

1. Maxwell's equations for optical waveguides
2. Material models for optical devices
3. Modes in slab waveguides
4. Modes in circular waveguides
5. Mode matching method for waveguide discontinuities
6. Coupled mode theory for non-uniform waveguides
7. Circuit formulation for photonic integrated circuits
8. Design of passive optical waveguides and integrated circuits.

Textbook/Reading: Course notes.

Grading:

Assignments	50%
Project	50%

Term: I

Electrical and Computer Engineering 755

Modeling and Simulation of Photonic Devices and Circuits II (Active and Functional Devices)

Instructor: Dr. Xun Li
CRL-218, Ext. 27698
E-mail: lixun@mcmaster.ca

Prerequisite: Electromagnetic Fields (3FI4), Solid State Devices I (4E03), Solid State Devices II (4F03), Modeling and Simulation of Photonic Devices and Circuits I (ECE-754)

Recommended Texts: Course notes

Course Description: Photonic devices and circuits are key components used for lightwave generation, amplification, transmission and detection in communication systems and networks. Photonic devices and circuits that utilize primarily photons, in conjunction with electrons can offer the tremendous bandwidth which is the key to a variety of applications, especially broadband communication systems and networks. This course will focus on the modeling of active and functional device physics through numerical approaches, the simulation of device terminal performances through mixed analytical and numerical methods and the extraction of device behavior models.

Course Outline:

1. Introduction to optoelectronic device modeling
2. Optical wave propagation
3. Optical property of semiconductors
4. Carrier transport in semiconductors
5. Thermal property of semiconductors
6. Numerical solution techniques
7. Selected device modeling and simulation examples

Grading: Midterm minor project 35%, Final major project 65%

Term: I

Electrical and Computer Engineering 756

Design of Lightwave Communication Systems and Networks

Instructor: Dr. S. Kumar
CRL-204, ext: 26008
Email: kumars@mail.ece.mcmaster.ca

Prerequisite: Communication Systems (3TI4), Discrete Time Systems and Random Processes (3TJ4), Computer Communication Networks (4DK4)

Recommended Texts: "Optical Fiber Telecommunications IIIA and IIIB", edited by I.P. Kaminow and T.L. Koch, Academic Press, ISBN 0123951704 (IIIA) and ISBN 0123951712 (IIIB)

"Fiber-Optic Communication Systems", Govind P. Agrawal, John Wiley and Sons, Inc., 1997, ISBN 0-471-17540-4

Course Description: Lightwave communication has emerged as the undisputed transmission method of choice in almost all areas of telecommunication, mainly because it offers unrivaled transmission capacity at low cost. Starting with the design of photonic devices for lightwave generation, modulation, amplification and detection and optical fibers for lightwave transmission, this course will mainly focus on the design of lightwave communication systems and networks based on these photonic devices and optical fibers.

Course Outline:

1. Lightwave generation and modulation
2. Fiber Transmission
3. Lightwave amplification
4. Lightwave detection
5. Advanced components for multiplexing and networking
6. Transmitter design
7. Amplifier design
8. Receiver design
9. Transmission protocols and line coding
10. Design of point to point WDM system
11. Transport networks, access networks and packet switched networks.

Grading: Project - 50%
Final Exam - 50%

Term: II

Electrical and Computer Engineering 757

Numerical Techniques in Electromagnetics

Instructor: Prof. Mohamed Bakr
ITB-A219, ext. 24079, e-mail: mbakr@mail.ece.mcmaster.ca

Support Lecturer: Prof. Natalia Nikolova
ITB-A220, ext. 27141

Prerequisite: EE3FI4 *Theory and Applications in Electromagnetics* or equivalent

Course Description: This course provides a solid understanding of the computational electromagnetic techniques used to model electromagnetic phenomena related to microwave and millimetre-wave engineering, antenna engineering and wireless technology. We adopt a systematic approach in which the complexity and dimension of the explained techniques are increased starting with simple 1D problems. Lectures will cover the following topics:

1. Fundamentals of electromagnetic theory-revision.
2. Green's functions in electromagnetic equations.
3. Method of Moments (MoM) and applications.
4. Finite Difference techniques and the Finite Difference Time Domain (FDTD) method.
5. Huygen's principle and the time domain Transmission Line Modeling (TLM) method.
6. Variational approaches in electromagnetics and the Finite Element Method (FEM).
7. The Mode Matching Method.
8. Recent advances in numerical electrodynamics-open discussion.

Recommended Texts:

1. C.A. Balanis, *Advanced Engineering Electromagnetics*, John Wiley and Sons, 1989
2. R.F. Harrington, *Time-Harmonic Electromagnetic Fields*, McGraw-Hill, Inc., 1961.
3. M.N.O. Sadiku, *Numerical Techniques in Electromagnetics*, CRC Press, 1992.
4. R.C. Booton, Jr., *Computational Methods for Electromagnetics and Microwaves*, John Wiley & Sons, 1992

Additional Resources: A selection of literature papers.

Evaluation: Four projects for 25% each
Students are expected to give presentations explaining their approaches. Part of the project grade is assigned to the presentation. All implementations are expected in Matlab.

Term: II

Electrical and Computer Engineering 760

Stochastic Processes

Instructor: Dr. T. R. Field

Webpage: http://www.ece.mcmaster.ca/fac_mems/field.htm

Recommended Text:

- Papoulis, A. and S. Pillai (2002). *Probability, Random Variables, and Stochastic Processes*, 4th edition, New York: McGraw-Hill, ISBN 0-07-366011-6.

Recommended Supplemental Texts:

- B. Oksendal (1998). *Stochastic Differential Equations - An Introduction with Applications*, 5th Edition, Springer.
- H. Risken (1989). *The Fokker-Planck Equation,* 2nd Edition, Springer.
- M. S. Bartlett (1966). *An Introduction to Stochastic Processes,* Cambridge University Press.

Course Structure and Outline: The course will consist of ten lectures, followed by an exam review week where the instructor will arrange set times to be available to answer questions related to the course. There will be one Mid-Term Exam based on Part 1 of the course, and a Final Exam based on Part 2.

The course is intended to provide a review of basic concepts in probability theory, leading to the introductory treatment of stochastic processes, with applications drawn from physics and engineering. Some introductory material on stochastic differential equation (SDE) theory will be included towards the end of the course as a precursor for students who intend to pursue this subject in more depth by attending a separate graduate course devoted entirely to SDE theory and its applications in electromagnetism.

The course is aimed at students towards the beginning of their PhD in Electrical Engineering, as well as those in Applied Mathematics and Theoretical Physics.

The material will be organised as follows (the timetable is subject to *minor* adjustments depending on interactions with the students during the term):

Part 1: Elements of Probability

- Lecture 1: meaning of probability, logical relations, conditional probability and expectation, Bayes theorem, Bayesian statistics
- Lecture 2: continuous random variables, probability density functions, marginal distributions, correlation functions, higher order statistics
- Lecture 3: moments, heavy tailed distributions, Cauchy distribution

- Lecture 4: complex valued processes, characteristic functions, stability/infinite divisibility, central limit theorem
- Lecture 5: statistical Hilbert space, Fisher information geometry, Cramer-Rao lower bound, efficient estimators, exponential distributions

Part 2: Stochastic Processes

- Lecture 6: Markov property, stationary processes, principles of ensemble and ergodic averaging
- Lecture 7: spectral density, auto-correlation, Wiener-Khinchin theorem, white and coloured noise processes, spectral shape, power and bandwidth
- Lecture 8: population dynamics and the master equation, birth-death-immigration (BDI) processes, the Poisson process, the continuum limit
- Lecture 9: heat equation, diffusion processes, drift and diffusion coefficients, Kramers-Moyal expansion, Fokker-Planck equation, asymptotic distributions, notions of drift, osmotic and current vectors, equilibrium and detailed balance conditions
- Lecture 10: discrete random walks, Brownian motion and the Wiener process, introduction to SDE theory with simple examples
- Week 11: exam review

Grading: Mid-Term (Part 1): 30%
Final Exam (Part 2): 70%

Term: II

Electrical and Computer Engineering 762

Detection and Estimation

Instructor: Dr. K.M. Wong

Course Description: This course introduces the fundamental ideas of signal detection and parameter estimation and aims at covering certain basic techniques in the processing of stochastic signals. The use of these concepts and techniques will be illustrated in a few specific applications, especially in communications and radar systems.

Pre-requisite: Knowledge in signals and systems, stochastic processes, analysis and linear algebra, typically those covered in an undergraduate electrical and computer engineering programme.

Course Outline:

1. Classical theory of hypothesis testing and detection criteria
2. Multiple hypothesis and composite hypothesis testing
3. Detection of signals in white noise – the correlator
4. Detection of signals in coloured noise – whitening filter and solution of Fredholm equations
5. Applications to communications and radar systems
6. Parameter estimation – concepts and cost functions
7. Bayes's estimate, maximum likelihood estimate, MAP estimates
8. Bounds on estimates
9. Linear mean-square estimates
10. Waveform estimation of stationary processes – The Wiener filter
11. Waveform estimation of non-stationary processes – The Kalman filter
12. Applications to communication and radar systems.

Student evaluation will be based on assignments and on projects.

Reference Books:

1. H.L. Van Trees, *Detection, Estimation, and Modulation Theory, Part I*, John Wiley & Sons, 1968.
2. H. V. Poor, *An Introduction to Signal Detection and Estimation*, Springer-Verlag, 1988.
3. L.L. Scharf, *Statistical Signal Processing*, Addison-Wesley, 1990.

Grading:

Assignments	50%
Project	50%

Term: I

Electrical and Computer Engineering 767

Multitarget Tracking and Multisensor Information Fusion

Instructor: Dr. T. Kirubarajan

Pre-requisites: ECE760 (Stochastic Processes) or ECE730 (Linear Systems) or ECE771 (Algorithms for Parameter and State Estimation) or instructor's permission.

Text: *Multisensor-multitarget tracking*, Y. Bar-Shalom and X. Li, YBS Publications, 1995.

Course description: This is intended as a follow-up course for ECE771, which deals with single-sensor single-target tracking in a clean environment. This new course will introduce the advanced concepts and algorithms for multisensor-multitarget tracking under realistic conditions (with imperfect sensors and measurement uncertainties). In addition, this course will deal with multisource information fusion with applications to communications, signal processing and target tracking.

Course outline:

1) Review of target tracking and state estimation
2) Single-sensor single-target tracking in a clean environment
3) Single-target tracking in clutter
4) Multitarget tracking in clutter
5) Introduction to multisensor fusion
6) Multisensor fusion architectures
7) Multisensor fusion algorithms
8) Distributed sensor fusion
9) Sensor resource management
10) Computational issues
11) Application to target tracking, communications and signal processing

Project description: The students are expected to formulate and solve an advanced multisensor-multitarget tracking/fusion problem and present simulations results from their MATLAB or C/C++ implementation.

Grading: 25% problems, 25% take-home exam and 50% project

Term: II

Electrical and Computer Engineering 769

ADAPTIVE FILTER THEORY

Instructor:

Text: S. Haykin, *Adaptive Filter Theory*, 5th ed., Prentice-Hall, 2012.

Recommended Reading:

S. Haykin, *Adaptive Filter Theory*, 4th ed., Prentice-Hall, 2002.

W. Liu, J. C. Principe, and S. Haykin, *Kernel Adaptive Filtering: A Comprehensive Introduction*, John Wiley & Sons, 2010.

T. Adali and S. Haykin, *Adaptive Signal Processing: Next-Generation Solutions*, John Wiley & Sons, 2010.

Course description: An adaptive filter optimizes the presence of a signal of interest embedded in unknown additive noise by automatically adjusting the free parameters of the filter in accordance with a prescribed statistically formulated algorithm. This course will develop the mathematical theory of various realizations of adaptive filters.

Course outline:

1. Review of Stochastic Processes and Models
2. Wirtinger Calculus
3. Wiener Filters
4. Linear Prediction
5. Method of Steepest Descent
6. Stochastic Gradient Approach
7. Least-Mean-Square (LMS) Adaptive Filters
8. The Langevin Equation and Statistical LMS Filter Theory
9. Method of Least Squares
10. Recursive Least-Squares (RLS) Filters
11. Contrasting the Underlying Properties of LMS and RLS Filters
12. Robustness
13. Transition from Linear to Nonlinear Adaptive Filters
14. Kernel Adaptive Filters
15. Applications
    - Biomedical Signal Processing

- Communications
- System Identification

Grading:

- Assignments 50%
- Projects 50%

Term: II

Electrical and Computer Engineering 771

Algorithms for Parameter and State Estimation

Instructor: Dr. T. Kirubarajan
Office: ITB-A313, ext. 24819
e-mail: kiruba@mcmaster.ca

Outline: This course presents parameter and state estimation algorithms for noisy dynamic systems. The objective is to present a comprehensive coverage of advanced estimation techniques with applications to communications, signal processing and control. In addition to theory, the course also covers practical issues like filter initialization, software implementation, and filter model mismatch. Advanced topics on nonlinear estimation and adaptive estimation will be discussed as well. The concepts will be put into practice by the students on realistic estimation projects.

Prerequisites: Engineering mathematics, linear systems, probability and stochastic processes

References:

1. Y. Bar-Shalom, X. Rong Li and T. Kirubarajan, *Estimation with Applications to Tracking and Navigation*, John Wiley & Sons, 2001.
2. R. G. Brown and P. Y. C. Hwang, *Introduction to Random Signals and Applied Kalman Filtering*, John Wiley & Sons, 1992.
3. F. L. Lewis, *Optimal Estimation*, John Wiley & Sons, 1986.
4. D. Manolakis, *Statistical and Adaptive Signal Processing: Spectral Estimation, Signal Modeling, Adaptive Filtering and Array Processing*, McGraw-Hill, 2000.

Course Outline:

1. Basic concepts:
   a. Maximum likelihood (ML) estimation
   b. Maximum a posteriori (MAP) estimation
   c. Least squares (LS) estimation
   d. Minimum mean square error (MMSE) estimation
   e. Linear MMSE (LMMSE) estimation
2. LS estimation for linear and nonlinear systems
3. Modeling stochastic dynamic systems
4. The Kalman filter for discrete time linear dynamic systems with Gaussian noise

5. Steady static filters for noisy dynamic systems
6. Adaptive multiple model estimation techniques
7. Nonlinear estimation techniques
8. Computational aspects of discrete time estimation
9. Extensions to autocorrelated noise and smoothing
10. Continuous time state estimation

Grading: Exams 50%; Projects 40%; Homework assignments 10%

Term: I

Electrical and Computer Engineering 772

Neural Network and Learning Machine

Instructor: Dr. S. Haykin
Office: CRL-105, ext. 24809
e-mail: haykin@mcmaster.ca

Texts: S. Haykin: *Neural Networks: A Comprehensive Foundation*, Prentice-Hall, 1995.

Course Description: Total of 13 lectures, organized as follows:

1. Learning Process: Learning rules. Statistical consideration of the learning process. Complexity and VC-dimension theory. Regularization theory.
2. Perceptrons: Single-layer and multilayer perceptrons. Back-propagation
3. Kernel-based machines: Radial-basis function networks. Support vector machines for pattern classification and nonlinear regression.
4. Committee machines: Boosting. Mixture of experts. EM algorithm.
5. Principal components analysis. Maximum eigenfilters. Generalized Hebbian algorithm.
6. Self-organizing maps.
7. Independent component analysis: Blind source separation.
8. Neuro-dynamic programming.
9. Nonlinear sequential state estimation: Extended Kalman filter. Unscented Kalman filter. Particle filters.
10. Dynamically driven recurrent networks.

Grading: The grades for this course will be based on 2 computer experiments.

Term: I

Electrical and Computer Engineering 775
Cognitive Dynamic Systems

Instructor: Dr. S. Haykin
Office: CRL-110, ext. 24809
Email: **haykin@mcmaster.ca**
Web: http://soma.mcmaster.ca/haykin.php

Text: Lecture notes; no textbook

Course Description: Total of 12 lectures, each occupying three hours. There will also be an orientation meeting before the beginning of the course.

1. Motivation through examples
2. Markov processes and simulations
3. Stochastic dynamic programming
4. Partially observable Markov and decision processes
5. Game theory
6. Reinforcement learning
7. Game theoretic learning
8. Application I: Cognitive radio
9. Application II: Cognitive radar
10. Application III: Sensor networks

Grading: Credit for this course will be based on 2 projects using simulations. 50% for each project.

Term: II

1. G. W. Bryant and G. S. Solomon, *Optics of Quantum Dots of Wires*, Artech House.
2. W. P. Kirk and M. A. Reed, *Nanostructures and Mesoscopic Systems*, Academic Press.
3. Rainer Waser, *Nanoelectronics and Information Technology - Advanced Electronic Materials and Novel Devices*, 2nd Edition, Wiley-VCH, 2005.
4. L. Novotny and B. Hecht, *Principles of Nano-optics*, Cambridge University Press.
5. C. M. Niemeyer, *Nanobiotechnology: Concepts, Applications and Perspectives*, Wiley-VCH, April 9, 2004.
6. R. Freitas, *Nanomedicine, Volume I: Basic Capabilities*, Landes Bioscience, 1st edition, October 15, 1999.
7. P. Prasad, *Introduction to Biophotonics*, Wiley-Interscience, April 8, 2003.
8. N. Maluf, *An Introduction to Microelectromechanical Systems Engineering*, Artech House 2000.
9. W. Trimmer, *Micromechanics and MEMS: classic and seminal papers to 1990*, IEEE.
10. G. T. A. Kovacs, *Micromachined Transducers Sourcebook*, McGraw-Hill, 1998.
11. M. Gad-el-Hak, *The MEMS Handbook*, CRC Press, 2002.
12. G. Karniadakis, A. Beskok, N. Aluru, *Microflows and Nanoflows: Fundamentals and Simulation*, Springer 2005.
13. Geshke, *Microsystem Engineering of Lab-on-a-chip Devices*, John Wiley Sons, 2004.
14. N. T. Nguyen, S. Wereley, *Fundamentals and Applications of Microfluidics*, Artech House Publishers, 2002.
15. Stephen D. Senturia, *Microsystem Design*, Kluwer Academic Publishers, 2000.
16. M. Madou, *Fundamentals of Microfabrication*, New York: CRC Press, 1997.
17. Rao Tummala, *Fundamentals of Microsystems Packaging*, McGraw-Hill Professional; 1 edition, May 8, 2001.
18. James E. Morris and Debendra Mallik, *Nanopackaging: Nanotechnologies and Electronics Packaging*, Springer; 1 edition, November 2007.
19. P. Rai-Choudhury, *MEMS and MOEMS Technology and Applications*, SPIE Publications, December 1, 2000.

Term: II

Electrical & Computer Engineering 778
Introduction to Nanotechnology

Instructor:

Course Description:

This course provides a fundamental knowledge in nanotechnology. It focuses on the new physical phenomena due to the reduction of device dimension and the new applications as a result of these new phenomena. The topics include nano-materials, nano-electronics, nano-photonics, nano-biotechnology, nano-MEMS and nano-integration. Students will learn what should be considered in the nano-world, what new applications we might be benefited from, and what precautions we need to pay attention when dealing with issues in the nano-world.

Course Outline:

1. **Nano-material:** it focuses on the material optical and electrical properties emerged in semiconductor nanostructures, including electron transport and correlation, Coulomb blockade, electron-phonon scattering, excitation dynamics, and photo-luminescence in low dimensional structures such as quantum wires and dots and those collective effects in nano-structure arrays. The modeling and simulation techniques involved will also be introduced.
2. **Nano-electronics:** it covers fundamental knowledge in dielectrics, electronics properties, quantum effects, ferroelectrics, magnetism, magnetotransport in layered structures, magnetoelectronics, organic molecules and neurons. It also talks about their applications in silicon MOSFETs, quantum transport devices based on resonant tunneling, single-electron devices for logic applications, high-permittivity materials for DRAMs, ferroelectronic random access memories, magnetoresistive RAM, carbon nanotubes and molecular electronics.
3. **Nano-photonics:** it includes surface plasmonic waveguides and resonators. It also covers FÖrster resonance energy transfer related optical gains.
4. **Nano-biology & nano-medicine:** it covers nanobiotechnology, nanomedicine, biocompatibility, biophotonics, nanophotonics, microfluidics, and lab-on-a-chip.
5. **Nano-MEMs:** it presents MEMS/NEMS, micro/nanofluidics, integration and assembly of micro/nanosystems.
6. **Nano-integration:** it covers nano-bonding and packing.

Grading:

Six mini-projects - 100%.

Electrical and Computer Engineering 791

Sensory and Neuromuscular Engineering

Instructor: Dr. Hubert de Bruin
ITB-A211, X24171, debruin@mcmaster.ca

Objective: To give the student a more detailed knowledge of engineering applications to sensory and neuromuscular physiology and medicine. The student will be introduced to sensory and neuromuscular physiology from an engineering perspective including equivalent circuits and models. The student will also gain experience in collecting electrophysiological or other physiological signals and in analyzing electroneurographic and electromyographic signals.

Text: S. Deutsch and A. Deutsch, *Understanding the Nervous System: An Engineering Perspective,* IEEE Press, 1993. ISBN 0-87942-296-3. Copies will be ordered as required

References: J.G. Webster, *Medical Instrumentation, Application and Design*, Third Edition, Houghton Mifflin, 1998.
A.C. Guyton, *Basic Human Physiology, Normal Function and Mechanisms of Disease,* (a number of different editions and variations)
B. Katz, ***Nerve, Muscle and Synapse,***
R.B. Stein, *Nerve and Muscle Membranes, cells and Systems,* Plenum Press, 1980

Course Outline: (Subject to Change)

- Sensory and neuromuscular anatomy and physiology.
- Acquisition and analysis of Electromyographic and Electro-neurographic signals to determine normal and pathological neuromuscular function
- Models of the myelinated and unmyelinated nerves including applied stimulating electrical fields
- Electrical fields in tissue resulting from surface and subcutaneous applied stimuli
- Surface and subcutaneous electrical fields in tissue resulting from single or populations of active nerve or muscle fibres
- Models of neuromuscular control
- Magnetic and electrical stimulation of neural structures
- Functional Electrical Stimulation (FES) and Magnetic Stimulation (FMS) in rehabilitation
- Neuroprostheses and sensory system interfaces.

Grading: Term Project (60%), Midterm (20%), Final (20%)

Term: II

Electrical and Computer Engineering 794
Robotic and Telerobotic Control Systems

Instructor: Dr. Shahin Sirouspour
Office: ITB-A319, ext. 26238
Email: **sirouspour@ece.mcmaster.ca**
Web: http://ece.mcmaster.ca/~sirouspour/

Prerequisites: A 3rd or 4th year course control systems (e.g. EE4CL4 or MECH ENG 4R03). An introductory course in Robotics (e.g. MECH ENG 4KO3) is helpful but not required. A solid background in mathematical analysis (linear algebra, differential equations, etc.) is essential.

Course Objective: To obtain a comprehensive understanding of the state-of-the-art in robotic and tele-robotic control systems. Topics to be covered range from the introductory rigid motions and coordinate transformations to advanced subjects such as design of controllers for teleoperation systems

Course Schedule: Lecture: 3 hours; time and location to be determined.

Course Outline:

- Rigid motions: vectors, frames, coordinate transformations and rotation matrices
- Robot heuristics: forward kinematic & differential kinematics and the Jacobian matrix, inverse kinematics
- Robot dynamics: Lagrange's formulation, dynamic equations and their properties
- Motion planning: joint-space trajectories, workspace trajectories
- Sensing and actuation: Electric, hydraulic and pneumatic actuators, position, force and tactile sensors, robot vision
- Rabot control: Lyapunov stability, position control, force control, hybrid control, impedance control.
- Image-guided control of robotic systems
- Introduction to tele-robotics: bilateral teleoperation architectures, performance requirements, stability requirements, network analysis of teleoperation systems, time delay in teleoperation systems, passivity analysis
- Controller design for teleoperation: linear controllers, adaptive nonlinear controllers, passivity-based controllers, robust controllers
- Haptic simulation

Textbook: L. Sciavicco aud B. Siciliano, *Modeling and Control of Robot Manipulators*, Second Edition, Springer-Verlag, 2000.

Other Recommended Reading:

- Articles that will be handed out in the class.
- M.W. Spong, S. Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, John Wiley & Sons, 2006.
- A. van der Schaft, *L_2-Gain and Passivity Techniques in Nonlinear-Control*, 2nd edition, Springer, 2000.
- M. Krstic et al, *Nonlinear and Adaptive Control Design*, John Wiley, New York, 1995.
- J.-J. Slotine and W. Li, *Nonlinear Control*, Prentice Hall, 1991

Grading:

Final Exam	30%
Course Project	50%
Assignments	20%

Term: I

Electrical and Computer Engineering 795
Quantitative Electrophysiology

Instructor: Dr. H. de Bruin, ITB-A211, Ext. 24171
e-mail: debruin@mcmaster.ca

Prerequisite: A basic undergraduate understanding of electrostatics, electrical circuits, linear systems, and ordinary and partial differential equations.

Course Description: This course provides a solid quantitative understanding of the behaviour of excitable cells, the resulting extracellular fields, measurement of extracellular fields using techniques such as EMG and EEG, and functional electrical stimulation of excitable cells for neural and muscular prostheses.

Course Outline:

1) Introduction to excitable cells; Equivalent electrical circuit for cell membranes
2) Cell excitability; Introduction to the Hodgkin-Huxley model
3) Linear cable equations; Propagation of electrical potential waveforms
4) Chemical synapses and gap junctions; Dendritic trees
5) Muscle physiology
6) Models for generation of extracellular fields
7) Electromyography (EMG)
8) Electroencephalography (EEG)
9) Measurement of bioelectric potentials (electrodes, differential amplification, filtering, data acquisition, etc.)
10) Electrodes and sources for functional electrical stimulation (FES)
11) Fundamentals of FES
12) Applications of FES

References:

R. Plonsey and R.C. Barr, "Bioelectricity: A Quantitative Approach", 2nd edition, Kluwer Academic/Plenum Publishers, 2000.

D. Johnston and S. M.-S. Wu, "Foundations of cellular neurophysiology", MIT Press, 1994.

C. Koch, "Biophysics of Computation: Information Processing in Single Neurons", Oxford University Press, 1998.

J. Malmivuo and R. Plonsey, "Bioelectromagnetism: Principles and Applications of Bioelectric and Biomagnetic Fields", Oxford University Press, 1995.

Grading: Assignments (15%); Project (25%); Midterm Exam (20%); Final Exam (40%).

Term: I

Electrical and Computer Engineering 796

Models of the Neuron

Instructor:

Dr. Ian Bruce,
CRL-229, Ext. 26984.
e-mail: ibruce@mail.ece.mcmaster.ca

Objective:

To provide a solid conceptual and quantitative background in the modelling of biological neurons and how they function as computational devices. Practical experience will be gained in modelling neurons from a number of perspectives, including equivalent electrical circuits, nonlinear dynamical systems, and random point-processes, and an introduction to the mathematics required to understand and implement these different engineering methodologies will be given.

Text:

C. Koch, *Biophysics of computation: information processing in single neurons*, Oxford University Press, 1998. (ISBN: 0195104919)

References:

P. Dayan and L. F. Abbott, Theoretical neuroscience, MIT Press, 2001. (ISBN: 0262041995)

D. Johnston and S. M.-S. Wu, Foundations of cellular neurophysiology, MIT Press, 1994. (ISBN: 0262100533)

C. Koch and I. Segev, Methods in neuronal modeling - 2nd edition, MIT Press, 1998. (ISBN: 0262112310)

H. Wilson, Spikes decisions and actions: Dynamical foundations of neuroscience, Oxford University Press, 1999. (Hdbk: ISBN 0-19-852431-5; Pbk: ISBN 0-19-852430-7)

W. Gerstner and W. Kistler, Spiking neuron models: single neurons, populations, plasticity, Cambridge University Press , 2002. (Hdbk: ISBN 0-521-81384-0; Pbk: ISBN 0-521-89079-9) Link to online version.

F. Rieke, D. Warland, R. de Ruyter van Steveninck, and W. Bialek, Spikes: exploring the neural code, MIT Press, 1996. (ISBN: 0262181746)

D. L. Snyder and M. I. Miller, Random point processes in time and space, Springer-Verlag, 1991. (ISBN: 0387975772)

S. H. Strogatz, Nonlinear dynamics and chaos: with applications in physics, biology, chemistry, and engineering, Perseus Books, 2001. (ISBN: 0738204536)

Lectures: There will be eleven 3-hour lectures, with the possibility of one extra, if required.

Prerequisite: A basic undergraduate understanding of electrical circuits, linear systems, ordinary and partial differential equations, probability and random processes.

Course Outline:

Introduction to Biological Neurons and Neural Computation (1 Lecture)

Basic anatomy and physiology of neurons, membrane potential, spiking, spike propagation, synapses, excitation and inhibition, basics of neural computation;

Simple Deterministic Models of Neural Excitation (2 Lectures)

Integrate-and-fire models, discharge-rate models, simple neural networks;

Stochastic Models of Neural Activity (2 Lectures)

Poisson- and renewal-process models, random-walk models;

Nonlinear Dynamical Models of Neural Excitation (3 Lectures)

The Hodgkin-Huxley model, ionic channels, activation and inactivation states, action potential generation, phase-plane analysis of neural excitability, nonlinear dynamics;

Axons and Dendritic Trees (3 Lectures)

Linear cable theory, modeling dendritic trees, action potential propagation, compartmental models.

Grading: Assignments (45%); Midterm (25%); Final (30%).

Term: II

Policy Reminders:

Senate and the Faculty of Engineering require all course outlines to include the following reminders:

"The Faculty of Engineering is concerned with ensuring an environment that is free of all adverse discrimination. If there is a problem, that cannot be resolved by discussion among the persons concerned, individuals are reminded that they should contact the Department Chair, the Sexual Harassment Officer or the Human Rights Consultant, as soon as possible."

"Students are reminded that they should read and comply with the Statement on Academic Ethics and the Senate Resolutions on Academic Dishonesty as found in the Senate Policy Statements distributed at registration and available in the Senate Office."

"The instructor and university reserve the right to modify elements of the course during the term. The university may change the dates and deadlines for any or all course in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes."

"Academic dishonesty consists of misrepresentation by deception or by other fraudulent means and can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. It is your re-sponsibility to understand what constitutes academic dishonesty. For information on the various kinds of academic dishonesty please refer to the Academic Integrity Policy, specifically Appendix 3, located at
http://www.mcmaster.ca/senate/academic/ac integrity.htm
The following illustrates only three forms of academic dishonesty:

1. Plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained. (Insert specific course information, e.g. style guide)
2. Improper collaboration in group work. (Insert specific course information)
3. Copying or using unauthorized aids in tests and examinations.

(If applicable) In this course we will be using a software package designed to reveal plagiarism. Students will be required to submit their work electronically and in hard copy so that it can be checked for academic dishonesty."