Spring 2015 Course Syllabus: Math 430-001

Course Title:	Analytical and Computational Neuroscience
Textbook:	"Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting" by E.M. Izhikevich, MIT Press (2007), 1st Ed., ISBN: 0-262-09043-8.
Prerequisites:	Math 211 or Math 213 with a grade of C or better, and Math 222 with a grade of C or better, and 100-level CS or Math 340 with a grade of C or better
Website:	https://web.njit.edu/~matveev/Courses/M430_635_F15/

Recommended Books:

- Mathematical Foundations of Neuroscience" by G. B. Ermentrout & D. H. Terman – Springer (2010), 1st edition - ISBN: 978-0-387-87707-5.
- "Foundations of Cellular Neurophysiology" by D. Johnston & S. Wu – The MIT Press (1995) - ISBN: 0-262-100053-3.
- "Biophysics of Computation - Information processing in single neurons", by Christof Koch. Oxford University Press, 1999. ISBN 0-19-510491-9.
- "Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems", by Peter Dayan and Larry F. Abbott. The MIT Press, 2001. ISBN 0-262-04199-5.

Course Objectives

- Students will gain understanding of cell physiology underlying neuronal excitability.
- Students will learn the Hodgkin-Huxley model of action potential generation and propagation.
- Students will learn models of neuronal spiking and bursting of different levels of complexity.
- Students will learn how to qualitatively analyze the behavior of solutions of ordinary differential equations using phase-plane analysis.
- Students will understand the concept of bifurcation of a dynamical system, and use it to analyze models of neuronal excitability.
- Students will learn how to use MATLAB to graphically analyze and numerically solve ordinary differential equations arising in neuronal modeling.

Course Outcomes

- Students can describe physiological mechanisms underlying an action potential in an excitable cell.
- Students are able to analyze the behavior of a non-linear ordinary differential equation using phase-plane analysis.
- Students are able to build and analyze models of spiking and bursting neurons.
- Students are able to write a MATLAB program to numerically solve ordinary differential equations arising in the modeling of neural excitability.
- Students will be able to find bifurcations of models of neural excitability and other ordinary differential equations.

Course Assessment

- The assessment of objectives is achieved through homework assignments and one class project, and the in-class midterm and final examinations.

Course Outline			
Lecture	Date	Topic	Assignment
1	9/3	Introduction: cell excitability and the nervous system	Emailed after class
2	9/8	Physiology of cell excitability: the equivalent circuit and Nernst potential	
3	9/10	Passive membrane properties: non-dimensionalization and dynamics	Emailed after class
4	9/14	Ordinary differential equations (ODEs) - Review of analytical methods	
5	9/17	Ordinary differential equations (ODEs) – Review of numerical methods	Emailed after class
6	9/21	Ordinary differential equations (ODEs) - numerical methods and MATLAB	
7	9/24	1D models: stability analysis	Emailed after class
8	9/28	1D models: phase-plane analysis and bifurcations	
9	10/1	1D models: integrate and fire, quadratic integrate and fire	Emailed after class
10	10/5	2D models: vector fields and phase-plane analysis	
11	10/8	2D models: phase-plane analysis: stability and bifurcations	Emailed after class
12	10/12	2D models: FitzHugh-Nagumo model	Emailed after class
13	10/15	Review for the midterm exam	
14	10/19	Midterm Exam	
15	10/22	2D models: more on bifurcations	Emailed after class
16	10/26	Physiology of cell excitability revisited	
17	10/29	Physiology of cell excitability: Ionic currents, activation and inactivation	Emailed after class
18	11/2	Biophysical 4D model: Hodgkin-Huxley equations I	
19	11/5	Biophysical 4D model: Hodgkin-Huxley equations II	Emailed after class
20	11/9	Biophysical 2D reductions of Hodgkin-Huxley model: Morris-Lecar model	
21	11/12	Biophysical 2D reductions of Hodgkin-Huxley model: continued	Emailed after class
22	11/16	Biophysical 3D models: time-scale separation and neuronal “bursting”	
23	11/19	Neuronal Bursting: Geometry and Classification	Emailed after class
24	11/23	Neuronal Bursting: Classification and Models	Emailed after class
25	11/30	Propagation of action potential: the cable equation 1	
26	12/3	Propagation of action potential: the cable equation 2	Emailed after class
27	12/7	Neuronal networks: two coupled cells	
28	12/10	Neuronal networks: two coupled cells	Project due

IMPORTANT DATES	
FIRST DAY OF SEMESTER	September 1, 2015
Midterm Exam	October 19, 2015
LAST DAY TO WITHDRAW	November 2, 2015
LAST DAY OF CLASSES	December 20, 2015
FINAL EXAM PERIOD	December 15-21, 2015

Grading Policy

Assignment Weighting	
Homework & Quiz	22 %
Course Project	16 %
Midterm Exam	28 %
Final Exam	34 %

Tentative Grading Scale	
A	86 – 100
B+	80 – 85
B	74 – 80
C+	68 – 74
C	62 – 68
D	56 – 60

Homework, Quiz and Project Requirements

- Homework will be emailed by the instructor by the end of each week, and will be due Thursday the following week; in-class quizzes may also be given, and will be announced in advance. A single course project will be assigned in the second half of the semester, and will be due at the last class of the semester. All graded work should represent the student's individual effort; group work is not allowed unless the instructor explicitly requests otherwise.

Academic Integrity Honor Code

- Honor code is taken very seriously at NJIT, ensuring fairness in grading for all students. All submitted course work should represent your individual effort, unless instructions for group work are explicitly given in the assignment. Instances of assignment copying or plagiarism are extremely easy to spot and will automatically lead to the referral of the case to the NJIT Dean of Students. The policy on academic integrity is available here: http://www.njit.edu/education/pdf/academic-integrity-code.pdf

Prepared by Prof. Victor Matveev, August 25, 2015